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AREAWIDE ASSESSMENT PROCEDURES MANUAL

VOLUME II

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
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15. SUPPLEMENTARY NOTES The manual is prepared as an information document and users planning manual to support the Agency's 208 areawide waste treatment management and planning effort. It is a joint effort of the Office of Research and Development and the Office of Water, Planning and Standards.

16. ABSTRACT Pertinent to the implementation of State and areawide planning under Section 208 of P.L. 92-500, this manual provides an environmental management statement of procedures available for water quality management with particular emphasis on urban stormwater. The manual summarizes and presents in condensed form a range of available procedures and methodologies that are available for identifying and estimating pollutant load generation and transport from major sources within water quality management planning areas. Although an annotated chapter is provided for the assessment of non-urban pollutant loads, the major emphasis of the manual is directed toward the assessment of problems and selection of alternatives in urban areas, with particular concern for stormwater related problems. Also included in the manual are methodologies for assessing the present and future water quality impacts from major sources as well as summaries of available information and techniques for analysis and selection of structural and nonstructural control alternatives.

This manual is structured to present problem assessment and impact analysis approaches for several levels of planning sophistication. Simple procedures are recommended for initial analysis to develop the insight and problem understanding to guide the application of more complex techniques where required. Presented in three volumes the specific sections are as follows: procedures for assessment of urban and non-urban pollution sources and loadings, pollutional load stream impact analysis, methodology for evaluation and selection of control alternatives, rainfall runoff and water quality model applicability, land use and rainfall data analysis, runoff and water quality monitoring and parameter handbook, and cost and performance of structural and nonstructural pollution control alternatives.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water quality, Assessments, Mathematical models, Systems analysis, Urban areas, Rural areas, Waste water--water pollution, Waste treatment, Rainfall, Runoff, Regional planning, Cost effectiveness--management methods	Areawide planning, Statistical analysis, Stream impact analysis, Treatment alternative evaluation, AAPM, Section 208, P.L. 92-500, Monitoring, Point source pollution, Nonpoint source pollution	13B

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APPENDIX A

MODEL APPLICABILITY SUMMARY

A.1 Introduction

Computer-based mathematical tools form an important and integral part of the arsenal of tools at the disposal of the 208 planner. They are, however, nothing more than tools. Like the calculator or handbook or slide rule, the user must know how they work, what they do, and most importantly what they do not do. Any model is at best only an approximation of reality, and a clear understanding of both the real situation and the approximations made by the model developer is vital to effective model use.

For the first time through the 208 program large-scale integrated wastewater management plans are being developed. It will be difficult to adequately analyze the complex sets of alternatives without having a model available on which to "try-out" these alternatives.

This appendix, then, is a brief summary of some of the models and techniques most likely to be used by the 208 planner. The list is not exhaustive, however the selected models represent a set of tools that others have demonstrated to be of value. They are not new or "research" ideas.

Several factors are worth mentioning:

1. All of these models are in use and undergoing continual change and updating. The descriptions, therefore, may not be up to date.

2. Most of the models have one or more derivatives, which may or may not be of equal utility.

5. This appendix is basically an assemblage of previously published information, edited for inclusion here. Prospective model users should refer to model documentation for complete descriptions.

Two reports (1, 2) have been recently published by the U.S. Environmental Protection Agency which provide much more comprehensive model analyses. They are:

1. "Evaluation of Water Quality Models: A Management Guide for Planners," by Systems Control, Inc. (SCI).

2. "Assessment of Mathematical Models for Storm and Combined Sewer Management," by Battelle Northwest.

These reports are the best of their type available, and should be used as references throughout the 208 planning process. The SCI report contains an excellent chapter on contracting for modeling services which is applicable to any modeling activity. They are available from the U.S. Environmental Protection Agency, Office of Research and Development (RD-682), Washington, D.C. 20460 (Attn: Harry Torno), or from the EPA Water Planning Division.

A.2 Model Selection and Evaluation

The key criterion in the evaluation and selection of models is the problem under study. There are numerous cases on record where a model has been selected first, and then the rest of the study structured around the model. The reason for this is the failure on the part of study personnel to recognize that the model is simply a tool to assist in the conduct of the study. Initially, the following questions should be addressed in model selection:

1. What is the problem to be solved;

2. What temporal resolution is required? Depending on the type of water quality problem and receiving water, seasonal or even annual calculations may be enough;

3. Is a model needed, and if so, what approach (computer, nomogram, hand calculations, etc.) is necessary? In the early stages of, say, a 208 study, one is interested in a gross assessment of relative loads and impacts on water quality of various sources, and a simple model or analytical method may suffice;

4. What input, calibration and verification data are available? The model selected must be calibrated, and adequate input data must be collected. If data is not there, or if adequate funds for data collection are not provided, the use of a complicated model may be ruled out.

If, after preliminary analysis, it seems that a model is needed, several further factors should be considered:

1. Availability of qualified personnel to do water quality studies. Regardless of the method selected, someone skilled in water quality analysis should be available. Any model, simple or complicated, requires a considerable amount of expert judgement in its application, and without this expertise, model application is highly likely to be a failure.

2. Availability of models that have already been calibrated and applied locally. The major costs in applying any computer-based model are in becoming familiar with the model and how it works, in collecting basic data for model application (most of these data remain the same, regardless of how many times the model is used), and in setting the model up on the local computer system. The economics therefore warrant a considerable effort in locating available tools.

A.2.1 Model Selection

When the decision has been made to use models, a careful and systematic examination of the available tools is warranted. The SCI study previously referenced (i) provides an excellent methodology for model evaluation and

selection, particularly for water quality models, and should be referred to by any potential model user. The following is a brief summary of questions to be considered in determining if the model is suitable for the problem under study:

1. What water quality constituents are to be modeled (if any) and can the model accomodate them? It may be enough at the outset simply to have a good feel what is going on hydraulically, without giving too much attention to pollutants;

2. Is the problem dynamic or steady-state? There seems little justification given the present state-of-the-art to do completely steady-state modeling of hydrologic phenomena. However, steady-state water quality models may be entirely satisfactory, particularly if design conditions for the plan are for steady-state flow (such as 7-day, 10-year low flow) and effluent loadings;

3. What are the spatial considerations? For streams, a one-dimensional model is adequate if homogeneous mixing across the river cross-section is an adequate assumption. For an estuary, on the other hand, a two- or even three-dimensional model may be required;

4. Has a model under consideration been used and tested, and is good, user-oriented documentation available? This is probably the most critical element to be considered;

5. If a proprietary model is considered, how will continuity in planning be accomodated? The planning process is an on-going one, and models are most economical when used repeatedly;

6. What are the costs of model replication? It is important to note here that computer costs are relatively insignificant, and that

the major costs of model use are personnel costs. In general, however, simpler models are cheaper to use than complex ones.

A.2.2 Model Evaluation

At the end of the selection process, the user should have a number of possible models which seem acceptable. A more systematic evaluation process should be undertaken at this point, along the lines of that described in the SCI report (1). While this report is directed primarily at water quality models, the same general methodology could be effectively applied to drainage models as well. The primary emphasis at this stage is in determining the relative resources required, and the data necessary for an effective modeling application. As a minimum, some formal comparative analysis should be conducted, even if only in simple tabular form. The analysis should be as objective as possible, using consistent evaluation criteria and weighting factors for all models.

If modeling work is to be conducted by a consultant, this same evaluation should be conducted, even though the consultant may have a "preferred" model that he normally uses.

A.3 Urban/Non-Urban Drainage Models

Drainage models form a key part of any areawide wastewater management assessment, whether they are simple hand calculations or the more complex computer-based models described here (see Table A-1). This group of models was arbitrarily selected based on the following criteria:

1. Generally available
2. Well documented
3. Tested and applied in several locations

Other models may meet the same criteria, and would be equally valid for the user, particularly if he were experienced in applying some other specific model.

TABLE A-1 URBAN/NON-URBAN DRAINAGE MODELS

Model	Author	Hydrology							Hydraulics							Hydrologic Quality									Miscellaneous					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	●	●	●	●	●	●	●	●	●		●		●	●	●	●	●	●		●		●	●	●	●	●		●	●	
[illegible]	[illegible]	●	●	●	●	●	●		●		●	●		●	●	●	●	●	●						●			●		●	
[illegible]	[illegible]	●	●	●		●	●	●	●	●	●	●		●	●	●	●	●	●		●	●	●	●	●	●		●		●	
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[illegible]	[illegible]	●	●	●		●	●		●					●	●													●	●		●

★ [illegible]

The shortcomings of the rational method or its derivatives are well documented, however it bears mentioning again that given the ease of application of some of the models herein described, particularly to the rainfall-runoff relationships, there appears to be no justification for using the rational method in any areawide management study, except as a part of a very preliminary screening analysis as described in Chapter 2. This is doubly true if storage or retention phenomena are to be examined.

All of the models described have demonstrated the ability to predict runoff quantity with sufficient accuracy, and with relatively little calibration required. This is not true of water quality. The models are very sensitive to pollutant accumulation and washoff functions, and most of the model calibration effort needs to be directed here. Runoff quantity can be roughly calibrated using streamflow data, or more detailed local flow measurements may be made. Runoff quality should be calibrated using current local information. One technique is to use a detailed model (SWMM) on one or more small subcatchments, then to extrapolate these results to the larger study area. It must be pointed out here that models frequently have "default" values for some or all of the calibration parameters. These are values which have been selected by the model developer as representative values. Default values may or may not, however, be appropriate for the local situation in which a model is used, and each calibration parameter should be carefully examined when a model is applied to determine if a default value is appropriate.

A.3.1 Drainage Models

A.3.1.1 STORM (Corps of Engineers)

The Storage, Treatment and Overflow Model (STORM) (3) of the Corps of Engineers Hydrologic Engineering Center is intended primarily for evaluating the stormwater storage and treatment capacity required to reduce untreated overflows below specified values. The model can simulate hourly stormwater runoff and quality for a single catchment for several years.

Five water quality constituents are computed for different land uses: suspended and settleable solids, biochemical oxygen demand, nitrogen, and phosphorus.

The model does not route flows and quality through a sewer network and does not have real-time and design capability. Its main purpose is the assessment of alternatives for treatment and storage of stormwater under varying land use conditions. Dry-weather flows and quality are not simulated; consequently the model is not applicable to combined sewerage systems (The Corps of Engineers is presently modifying STORM to include dry-weather flow). The STORM model includes the following features:

1. Rainfall, snowfall, air temperature, and evaporation at one weather station;

2. Evapotranspiration;

3. Snow accumulation and melt;

4. Stormwater quality for different land uses;

5. Suspended and settleable solids, biochemical oxygen demand, nitrogen, and phosphorus;

6. Stormwater runoff and quality from pervious and impervious areas of a single catchment;

7. Catchment moisture accounting during periods of no precipitation;

8. Capacity of storage facilities;

9. Hydraulic capacity of treatment facilities; and

10. Volume and quality of overflows.

The model does not include the following features:

1. Dry-weather flow and quality;

2. Consideration of nonuniform catchment and precipitation distribution;

3. Stormwater runoff and quality from more than one catchment;

4. Flow and quality routing in gutters, sewers and open channels;

5. Wastewater quality decay, reactions and interactions;

6. Wastewater quality improvement by treatment;

7. Real-time control;

8. Design; and

9. Costs.

Hourly stormwater runoff is defined as the product of a runoff coefficient and hourly rainfall excess. Only one precipitation record can be used. The runoff coefficient is the weighted average of empirical runoff coefficients for the pervious and impervious areas and represents the fraction of rainfall excess lost to infiltration. The rainfall excess is defined as the difference between hourly rainfall and losses to depression storage. The depression storage at the beginning of a rainstorm is defined as the available depression storage at the end of the previous rainstorm plus a linear recovery to account for evaporation during the period of no precipitation. A different evaporation rate can be specified for each month of the year. Snowmelt is computed by the degree-day method which requires mean daily air temperature as input data.

The runoff coefficients, available depression storage, and depression storage recovery factor have to be derived by calibration with observed data. Default values are given in the program but no instructions are provided for estimating adequate values for ungaged catchments. Dry-weather flow is not simulated.

The computations for the stormwater runoff quality are based on formulations first used in the EPA Stormwater Management Model, which simulated only suspended solids, biochemical oxygen demand, and coliform bacteria. The STORM model has been expanded to simulate suspended and settleable solids, biochemical oxygen demand (BOD), nitrogen (N), and phosphorus (P). Empirical equations considering land use, street sweeping practices, and days between rainstorms define the amount of each pollutant on the ground at the beginning of a rainstorm. An exponential function of the runoff rate determines the rate of each pollutant being washed off the catchment during each hour. The rates of runoff of BOD, N, and P are assumed to be dependent on the rate of runoff of suspended and settleable solids.

The runoff quality formulations depend on a large number of empirical coefficients which have been derived from very limited urban stormwater runoff and quality data. The coefficients are internal to the program and do not account for variations in land use and catchment characteristics. Application of the model in different areas may therefore require programming changes to modify the coefficients. Input data which may be difficult to obtain include daily rate of dust and dirt accumulation and the percent of each pollutant contained in the dust and dirt for different land uses (in addition to model documentation, user may refer to Chapter 5 and other EPA guidance (20) for guidance in determining accumulations). Default values are provided by the program. Dry-weather quality is not considered by the model.

Computations of treatment, storage and overflow proceed on an hourly basis by simple runoff volume and pollutant mass balance. If the hourly runoff exceeds the treatment capacity, the excess runoff is put into storage. If

the storage capacity is also exceeded, the excess runoff becomes untreated overflow. If the runoff is less than the treatment capacity and water is in storage, then the excess treatment capacity is utilized to diminish the storage volume.

Plug flow is assumed for the routing of pollutants through storage. The water quality is not modified in storage. For treatment, only the hydraulic capacity of treatment facilities is considered. Stormwater quality improvement by treatment is not modeled.

The computer program, written in Fortran IV for the UNIVAC 1108 computer is available from the Hydrologic Engineering Center of the Corps of Engineers. The simulations require 1-hour time steps and a minimum of 24 hours of simulation. Several years of data can be simulated in a single run; the maximum duration depends only on computer running costs and the objective of the analysis.

Program output includes hourly precipitation for a single raingage and various summaries of the stormwater runoff and quality analysis for selected storm events. These include the duration and amount of rainfall, the time and amount of treatment, the amount of runoff, the utilization and age of storage, the amount of overflow to receiving waters, and averages for all selected events. Runoff amounts are defined in inches and pollutant quantity in pounds. In addition, tables and line printer plots are available indicating the utilization of storage (see Appendix d for additional cost information).

A.3.1.1.1 STORM Input Data

STORM requires the following input data:

1. Area of drainage basin;

2. Percent of total area in each of 5 land use groups;

3. Average per cent imperviousness of each land use group;

4. Runoff coefficients for pervious and impervious areas;

5. Feet of gutter per acre for each land use group.

6. Depression storage available on impervious areas;

7. Treatment rate;

8. Hourly rainfall;

9. Daily rate of dust and dirt accumulation per 100 feet of gutter for each land use group;

10. Pounds of pollutants per 100 pounds of dust and dirt;

11. Street sweeping frequency and efficiency.

A.3.1.1.2 Evaluation of STORM

The model is suitable for the continuous simulation of stormwater runoff and quality from a single urban catchment. A significant weakness of the model is its inability to simulate dry-weather flow and quality.

Limitations on accuracy of the runoff computations are imposed by the simplified rainfall-runoff formulation, particularly the assumptions of a constant infiltration loss rate during rainstorms, a constant evaporation rate between rainstorms, and immediate runoff of the hourly rainfall excess. The last approximation would reduce model accuracy as the catchment size increases and the time of concentration of the runoff becomes longer than one hour.

The stormwater quality relationships are based on empirical formulations which have been tested on very limited data and whose accuracy has not been

sufficiently established. It is therefore not possible to estimate their accuracy for application to areas where no records of concurrent urban stormwater runoff and quality are available for calibration purposes.

The model appears to be useful, however, for analysis of rainfall records to determine critical runoff-producing events and for general planning purposes to estimate the relative magnitudes of required storage and treatment capacities to reduce stormwater overflows below desired levels. The model computes only the quality of the overflows to the receiving waters. Addition of the computation of the quality of the treatment plant effluents would be desirable to obtain the total pollutant load on the receiving water.

A.3.1.2 SWMM (EPA)

The U. S. Environmental Protection Agency's Stormwater Management Model (SWMM) (4, 3) is one of the most comprehensive mathematical models available for the simulation of storm and combined sewerage systems. It computes the combined storm and sanitary runoff from several catchments and routes the flows through a converging branch sewer network. Flow diversion structures can be modeled and storage can be simulated for both inline and overflow retention basins. An additional feature is a receiving water model which includes nonsteady formulations of hydrodynamics and mass transport for two-dimensional (vertically mixed) water bodies receiving sewerage system effluents. Both dry-weather and stormwater quality for suspended and settleable solids, biochemical and chemical oxygen demand, coliform bacteria, phosphorus, nitrogen, and oil and grease are computed for each modeled catchment and routed through the sewerage system. Mathematical formulations which simulate various combinations of overflow treatment processes for one treatment facility are included to evaluate the effectiveness of overflow treatment. The model does not include realtime control features. The model is limited to the simulation of single runoff events and inline treatment cannot be simulated. Cost functions are built into the program to compute the cost of overflow storage and treatment. The SWMM is organized into an executive block (MAIN) and four computational

blocks (RUNOFF, TRANSPORT, STORAGE, RECEIVE) which may be used separately or in any combination to simulate the entire urban drainage area.

The Stormwater Management Model includes the following features:

1. Dry-weather flow and quality of several catchments from land use;

2. Several rainfall records;

3. Stormwater runoff and quality for pervious and impervious areas of catchments with several land uses;

4. Eight water quality constituents: suspended and settleable solids, biochemical and chemical oxygen demand, coliform bacteria, phosphorus, nitrogen, oil and grease;

5. Flow routing in gutters;

6. Routing of combined wastewater flow and quality in a converging branch network;

7. Twelve specified closed conduit cross sections, a trapezoidal section, and two arbitrary shapes;

8. Backwater, surcharging and pressure flow;

9. Two types of diversion structures;

10. Pumping stations;

11. One overflow and two inline storage facilities with four types of outlet facilities;

12. Sedimentation and scour of suspended solids;

13. First-order water quality decay of BOD;

14. Removal of coliform dependent on suspended solids removal;

15. One overflow treatment plant with arbitrary combinations of nine unit treatment processes;

16. Costs of storage and treatment;

17. Receiving water flow and quality; and

18. Sizing of circular pipes.

The model does not include the following features:

1. Evapotranspiration;

2. Snow accumulation and melt;

3. Catchment moisture accounting during periods of no precipitation;

4. Sewer flow and quality routing in loops and diverging branches;

5. Downstream flow control and flow reversal;

6. Water quality reactions and interactions in the sewers and in storage; and

7. Real-time control.

Dry-weather flow and quality of eight constituents can either be provided as average values or computed from land use characteristics such as total population, population density, land use, residential income and home valuation of each subcatchment. Adjustment factors can be read in for

diurnal (hourly) variations in flow and quality. Weekday adjustment factors can be read in for all but coliform bacteria. Industrial or commercial process flows and quality can be input separately.

Rainfall intensities of several raingages can be provided as input data to compute storm runoff from several catchments. Only one raingage record can be assigned to a particular subcatchment.

Losses are subtracted separately from the rainfall falling on pervious and impervious areas. Runoff occurs only when all depression storage is filled. No other losses are computed for impervious areas. Evaporative losses are not computed.

For pervious areas, the potential infiltration is computed with Horton's equation and the actual infiltration depends on the available overland flow depth. This is a more accurate computation than basing the infiltration losses on the amount of rainfall. Horton's equation, on the other hand, computes the potential infiltration as a function of time only and does not account for the change in potential infiltration with changes in soil moisture. The equation is satisfactory as long as the available moisture is greater than the potential infiltration, but errors are introduced during low intensity and intermittent storms when the available moisture is less than the computed potential infiltration. As a consequence, the infiltration coefficients of the equation have to be adjusted for different storms (theoretically they should be based on catchment soil characteristics only, independent of the storm patterns). This makes it difficult to use one set of coefficients with confidence for prediction purposes.

Overland flow is computed separately for pervious and impervious areas using a kinematic wave formulation with Manning's equation. A similar formulation is used for the gutter flow routing. The model formulation assumes that overland flow length and catchment length are equal. This assumption is satisfactory for small catchments, such as individual lots and possibly city blocks, but errors are introduced if the difference

between overland flow and catchment length increases (as occurs when several city blocks are lumped into a single subcatchment). The model assumes that infiltration occurs throughout the time required for the overland flow to run the entire length of the catchment. Actual infiltration, however, may occur only during the time it takes the overland flow to run the length of a single lot. As a consequence, the computed infiltration would be greater than the actual infiltration and the computed runoff hydrograph would be underestimated. Users of the model can compensate for this error by reducing the infiltration coefficients.

Infiltration from the ground into the sewers accounts for dry-weather infiltration, wet-weather infiltration, melting residual ice and snow infiltration, and groundwater infiltration. Average infiltration values for the entire modeled drainage basin have to be provided as input data. The entire catchment infiltration is then apportioned to individual sewers on the basis of the conduit perimeter and number of joints in each conduit. A degree-day method is used to compute the infiltration from snowmelt, but the accumulation of snow and surface runoff from snowmelt is not modeled. The effect of the infiltrating water on the quality of the sewage is considered negligible and not modeled.

Flow routing in the sewers is accomplished using the kinematic wave equation with Manning's equation. The basic formulation neglects downstream flow control, backwater, surcharging, pressure flow and flow reversal. Special formulations are incorporated in the model, however, to approximate backwater, surcharging and pressure flow. General downstream control and flow reversal are not modeled.

An optional transport block has recently been added. The primary differences may be summarized in three categories:

1. Conceptual representation of the transport system. WRE Transport Block uses a node-link idealization totally unlike the original SWMM Transport Block.

2. Basic flow equation. The WRE Transport Block includes the inertial terms of the Navier-Stokes equations in the solution, whereas original SWMM Transport Block is based on a kinematic wave assumption.

3. Special effects and flow control devices. The WRE Transport Block includes the effects of pipe surcharge, looped sewers, weirs, pumps and orifices plus some related features.

Backwater is modeled by formulating a special backwater element with an inline storage element of fixed length and simulating it with a storage routing technique. This requires input data on flow depth versus storage volume which is difficult to compute for special sewer shapes (such as horseshoe shapes, etc.) with a nonzero invert slope. Also, the assumption of a constant backwater length appears to make the formulation highly approximate. Since the program permits only two inline storage elements, backwater can be considered at only two locations in the entire sewerage system. Also definition of a backwater element reduces the number of actual storage facilities that can be modeled.

If surcharging occurs, the model assumes that all water in excess of full pipe flow capacity is stored in the next upstream manhole. The formulation neglects the storage volume of the manhole and the actual propagation of the surcharging farther upstream. The formulation consequently serves only to conserve volume and to warn the user that surcharging conditions exist, without adequately computing the phenomenon. Conduits can be sized by the program to advoid surcharging.

The flow routing scheme is formulated for 12 specified closed conduit cross sections and a trapezoidal section. In addition, two arbitrary conduit shapes can be specified by providing input data relating the dimensions of each shape to flow area, hydraulic radius, and discharge.

Two types of flow diversion structures can be modeled. The first type assumes that all inflow exceeding a maximum value is overflowed. No data

are needed to describe the geometry of this type. The second type assumes that no overflow occurs until the inflow exceeds a specified value. In this case, the depth of flow is found from a linear relationship between flow and depth and the overflow computed from this depth with a weir discharge equation. A more accurate formulation would be possible based on the weir and orifice equations.

Pumping stations can also be modeled. The model assumes that the pumps begin to operate at a constant pumping rate when the volume in the wet well reaches a maximum value and continue to pump until the wet well is pumped dry.

The model can simulate the performance of one overflow and up to two inline storage facilities. The model computes depth and volume of storage as a function of the inflow and outflow. The outflow is computed based on the hydraulic performance of the following four options of outflow conditions: gravity with orifice centerline at zero storage tank depth; gravity with fixed weir; gravity with both weir and orifice; and fixed rate pumps. Either regularly or irregularly shaped reservoirs can be specified by different input data. If a reservoir overflows, program execution terminates.

Stormwater quality is computed as a nonlinear function of stormwater runoff rate (which includes an exponential decay with time to account for the higher rates of pollutants being washed off during the beginning of a storm). Coefficients in equations for each of the three modeled pollutants account for different land uses. The equations consider street sweeping practices and days between rainstorms in defining the amount of each pollutant on the ground at the beginning of a rainstorm. The formulations account also for the contribution of accumulated BOD in catch basins. Many of the coefficients in the formulations are internal to the program and have been derived from very limited data of measured stormwater runoff and quality. Programming changes may therefore be required to apply the model to different areas and land use characteristics.

Stormwater and dry-weather qualities are combined at inlet manholes and routed through the sewers according to the flow velocity of the sewage. Dispersion is not modeled directly, but by averaging qualities between successive time steps. The equations consider first-order decay of BOD and sedimentation and scour of suspended solids. Reactions and interactions between the pollutants during the routing are not considered.

Nine overflow treatment processes can be modeled and arranged by the user in any series or combination. The modeled unit processes are: bar racks, fine screens, sedimentation, dissolved air flotation, dissolved air flotation preceded by fine screens, microstrainers, high-rate filters, effluent screens, and chlorination. Mathematical formulations for each process relate hydraulic capacity to removal efficiency. The user does not have the option of varying the process efficiencies without changing coefficients internal to the program. For some processes, however, the amount of chemicals used is read in to account for their effect on treatment performance.

BOD removal and suspended solids removal are considered independently. Coliform removal, however, is defined as a function of suspended solids removal.

Cost functions are built into the model which compute the cost of overflow treatment. Separate functions are defined for each unit treatment process and for storage and pumping if part of the treatment facility. Annual capital costs, land costs, and operation and maintenance costs are related to hydraulic capacity by power functions. The shapes of the cost functions are defined internally by the program. Costs can be adjusted by reading in the Engineering News Record index for regional adjustments and future expected changes.

The Stormwater Management Model includes also a receiving water flow and quality segment which is based on the original EPA dynamic estuary model. It gives the model the capability not only of modeling flow and quality in

sewerage systems, but of assessing the impact of the sewerage system effluents on the receiving water quality.

The flow computations of the receiving water models are based on a simplified explicit finite difference solution of the one-dimensional flow fields represented by an irregular grid of links and nodes. The continuity equation is solved at the nodes (junctions of the links) and the momentum equation is solved along the links (channels between the nodes). The model is very costly to use since very short time steps are required for numerical stability. The formulation becomes unstable if the discarges in adjacent channels and storage volumes of adjacent nodes are not of the same order of magnitude.

The model includes the transport of several conservative and nonconservative water quality constituents, considering first-order decay. Transport is modeled by convection only and chemical and biological interactions between different water quality constituents are not considered.

The computer program, which is available from the U.S. Environmental Protection Agency, is written in FORTRAN IV for an IBM 360/370 computer and is also compatible with UNIVAC and CDC computers. There are five main programs which, depending on computer core storage capacity, can be either loaded together or in sequence depending on the user's needs.

Fairly complete documentation of the model is published by the EPA, including a summary report and user's manual. Unfortunately, no one of these reports presents a complete description of the theoretical bases and mathematical formulations of the model.

The equations for some modeled phenomena are described in the user's manual, and some are not described at all. The reader must compare the two reports to obtain a fair understanding of the capabilities and limitations of the complete model and the meaning of the input data. Also, the user's

manual includes much discussion of model verification and testing which adds to the report's bulkiness and makes it more difficult to find essential information for the preparation of input data.

Program output includes tables and line printer plots of rainfall intensities for each raingage, combined runoff and quality for each subcatchment, and routed discharges and water quality at selected points of the sewerage system. Summaries of treatment effectiveness and costs are also available. Water levels and flow velocities in the sewers are not computed.

A.3.1.2.1 SWMM Input Data

The input data requirements for SWMM are extensive, and include:

1. Rainfall data, antecedent dry days;

2. Subcatchment descriptions including area, overland flow width, slope, roughness coefficients, infiltration rates, percent imperviousness;

3. Land use, population data;

4. Street sweeping frequency and number of passes;

5. Soil erosion data;

6. Pollutant loading and generation factors;

7. Sewer layout, shapes, dimensions, slope, roughness;

8. Specifications of flow control devices;

9. Infiltration data;

10. Dry-weather flows;

11. Catch basin data;

12. Treatment and storage facility data;

13. Tidal variations, water surface elevations and areas, water depths and roughness coefficients for receiving waters; and

14. Receiving water boundary conditions.

A.3.1.2.2 Evaluation of SWMM

The EPA Stormwater Management Model is one of the most complete and widely used mathematical models available for the assessment and planning of storm and combined sewerage systems. Consideration of both wastewater flows and qualities is an important aspect of evaluating needed treatment facilities and the impact of sewage effluents on receiving waters. This is also one of the few models which include cost computations. Although the model does not consider costs in the sizing of sewers, the computation of the costs of overflow storage and treatment should be a valuable aid to the engineer.

Program limitations which may restrict the model's general applicability include the neglect of downstream hydraulic controls (with the exception of very rough approximations of backwater and surcharging conditions) and the absence of formulations for inline treatment and main treatment plants.

The model can be used only for the simulation of individual runoff events since it does not include provisions for either catchment moisture or water quality accounting between rainstorms.

The new version of the program includes an option to suppress the water quality computations and perform the flow simulations alone. This can save considerable computer time if water quality computations are not needed.

The model is very complex and a major effort is required to implement it. The poorly organized documentation makes it difficult for the user to implement the model resulting from misinterpretations of the theoretical bases of the model and the meaning of some input data.

The model has been tested extensively on urban hydrologic data. Numerical testing of the flow computations with data from catchments ranging in size between 5 and 2200 ha (13 and 5400 acres) showed satisfactory accuracy. The accuracy of water quality predictions can be expected to be only of the right order of magnitude. Considerable model improvement, particularly of the formulations relating water quality with land use, are needed before the water quality model can be used with confidence.

Improvements are needed in the output formats. The arrangement of the catchment runoff table makes it difficult to abstract the hydrograph of a particular subcatchment. Complete output of routed flow and quality can be obtained at only twenty selected locations. This is adequate for the evaluation of a few important locations, such as major outfalls. It is a serious limitation, however, for the evaluation of an entire sewerage system since repeated runs of the same data are required to obtain sufficient information on the adequacy, performance, and utilization of all modeled sewer system elements.

Model improvements are in progress at the University of Florida under an EPA contract to add snowmelt, to include more accurate flow and water quality routing schemes, to add new water quality parameters and unit treatment processes, and to simulate inline (main) treatment processes. A new and improved user's manual (5) has been prepared. The model is also being revised to add continuous simulation capability for planning purposes. The model is being used by many consulting firms, and is available for users on several commercial time-sharing computer systems.

A.3.1.3 HSP (Hydrocomp)

The Hydrocomp Simulation Program (6) is one of the most comprehensive mathematical models for the simulation of both rural and urban catchments.

The water flow computations are based on the Stanford Watershed Model which was the first comprehensive mathematical model of catchment hydrology. The Hydrocomp Simulation Program, however, is a considerable improvement over the original Stanford Watershed Model, both with respect to mathematical formulations and data handling capability. Recently, a separate program was developed for the simulation of water quality in river basins which can be interfaced with the hydrologic and flow routing program (see A.4.1.7).

The Hydrocomp Simulation Program is formulated for the continuous simulation of water flow and quality from several catchments and routing in converging branch sewer and open channel networks. Catchment moisture and water quality are accounted for during periods of no precipitation, so the model can be used for continuous simulation of several years. Special features are included for the simulation of impoundments and diversions, including the flow of water over spillways and through hydroelectric turbines. Real-time control and design and cost features are not included.

The Hydrocomp Simulation Program includes the following features:

1. Dry-weather flow and quality of several catchments;

2. Rainfall, snowfall, pan evaporation, air temperature, dew point, solar radiation, and wind velocity of several weather stations;

3. Evapotranspiration;

4. Snow accumulation and melt;

5. Stormwater runoff and quality from pervious and impervious areas of catchments with several land uses;

6. Catchment moisture and water quality accounting during periods of no precipitation;

7. Groundwater infiltration into sewers and open channels;

8. Seventeen water quality constituents with reactions and interactions in natural (receiving) water bodies;

9. Routing of combined wastewater flow and quality in a converging branch network;

10. Circular closed conduits and trapezoidal open channels with trapezoidal flood plains;

11. Upstream and downstream flow control and backwater;

12. Diversion hydrographs;

13. In-line storage reservoirs with rule curve operation; and

14. Water quality decay, reactions, and interactions in natural (receiving) water bodies.

The model does not include the following features:

1. Dry-weather flow and quality from land use;

2. Flow reversal, surcharging and pressure flow;

3. Sedimentation and scour;

4. Water quality decay, reactions and interactions in sewers;

5. Flow and quality routing in loops and diverging branches;

6. Noncircular closed conduits;

7. Sewer flow control and diversion structures;

8. Pumping stations;

9. Wastewater treatment;

10. Real-time control; and

11. Design and costs.

The Hydrocomp Simulation Program includes the most complete formulation of catchment hydrology of all the models listed. The model computes runoff from pervious and impervious areas separately and considers evapotranspiration, snowmelt, and soil moisture accounting.

Precipitation (rain or snow) data is input at constant time intervals for one or more raingages. Other meteorological data needed for the evapotranspiration and snowmelt computations are provided on a daily basis. Not more than one precipitation record can be assigned to a single subcatchment.

Snow accumulation and melt are computed by a method developed by the U.S. Corps of Engineers. The equations require data on precipitation, air temperature, dew point, solar radiation, and wind velocity. Programming defaults are used if some of these data are unavailable. Only precipitation and air temperature are essential.

Dry-weather flow and quality data are input at constant time intervals. Dry-weather quality can also be defined by a power function of dry-weather flow.

The potential infiltration rate is computed from an empirical function of soil moisture. The actual infiltration depends on the rainfall excess after subtracting interception losses rather than on the overland flow depth. The infiltrated moisture is divided into upper zone and lower zone storage. Upper zone storage includes depression storage. Part of the upper zone storage percolates into the lower zone storage and the rest is divided into overland flow and interflow, which become channel (or sewer) inflow. The lower zone storage is divided into a channel inflow

contribution and into deep groundwater storage which does not contribute to surface runoff.

Interception, upper zone, lower zone, and groundwater storage are depleted by evaporation or evapotranspiration computed as functions of potential evapotranspiration and available moisture.

Overland flow is routed with a modified kinematic wave formulation using Manning's equation. Several empirical coefficients internal to the program relate surface detention storage to overland flow discharge.

Although the model's representation of infiltration, groundwater percolation and storage, overland flow, groundwater contribution to surface flow, and evaporation from all moisture sources is based on physical concepts, the mathematical formulations are based largely on empirical relationships. They require several empirical coefficients, some of which are defined as soil moisture capacities. The model appears sufficiently complex that its use for prediction purposes without initial calibration with measured data may not be very reliable. Simpler models with fewer empirical coefficients seem adequate to model infiltration and surface flow contributions in urban catchments.

Flow routing in sewers and open channels is also accomplished using the kinematic wave equation with Manning's equation. The solution considers the geometry of circular pipes and of trapezoidal open channels with trapezoidal flood plains. A diffusion term in the kinematic wave equations approximates downstream flow control and backwater conditions. Surcharging and pressure flow in sewers is not modeled but a warning is printed if it occurs. The time step for the routing computations is computed internally to maintain numerical stability.

Reservoirs and channels can be simulated in the channel network. Storage capacity has to be defined as a function of depth and reservoir discharge has to be defined by rule curves relating discharge with time. Diversions are modeled by requiring diversion hydrographs as input data.

The computation of stormwater quality is based on formulations first used by the EPA Stormwater Management Model and then expanded in the Corps of Engineers' STORM Model and Water Resources Engineers' Stormwater Management Model. The concentration of each pollutant washed off a catchment is computed as a nonlinear funtion of runoff. Special empirical functions are built in for water quality balance between runoff events to account for dirt and dust accumulation, natural decay, street cleaning practices, and different land uses. The pollutant accumulation betwen runoff events can vary with the calendar month. Different values can be specified for pervious and impervious areas. The equations and coefficients have not been sufficiently tested for reliable predictions without calibration with measured data.

Pure advection is used to route pollutants through the sewer and open channel network. Dispersion is approximated by a weighted average of concentration values at successive time steps. For receiving water bodies, chemical and biological reactions and interactions among the seventeen modeled water quality constituents are computed. Only one-dimensional flow and water quality routing is formulated. Vertical water quality interchange can be approximated among three horizontal layers in impoundments by providing empirical mixing coefficients. The model documentation does not indicate whether reactions are computed for sewage. The model does not include formulations for wastewater treatment, real-time control, or design and cost computations.

The Hydrocomp Simulation Program is a proprietary model developed by Hydrocomp International, Inc., of Palo Alto, California. Separate user's manuals are available for the flow and water quality computations of the model. These contain sufficient detail covering the mathematical bases of the modeled phenomena and the required input data. The user must contract with Hydrocomp for routine application of the program. The firm conducts periodic workshops to instruct potential users in hydrologic simulation methods and application of the Hydrocomp Simulation Program.

The computer program consists of four main programs and is compatible with IBM 360 and 370 computers with a minimum of 240K bytes of core memory. Information is not published which would allow estimates of computer execution times as a function of problem size.

Computer output includes precipitation; soil moisture status; water stages, velocities, discharges, and water quality concentrations for all channels and storage; and volume of storage. Data input and output can be in metric or British units.

A.3.1.3.1 HSP Input Data

Input requirements are extensive and include:

1. Precipitation data;

2. Potential evapotranspiration;

3. Temperature;

4. Streamflow; and

5. HSP calibration parameters (includes such things as infiltration, depression storage, soil moisture storage, snow parameters, channel characteristics, watershed segments and channel reaches). Determination of these parameters requires considerable user skill and experience, since not all are measured directly.

HSP has extensive data handling capability, which simplifies the problem of assembling and managing the data required. This is a very attractive feature of this program.

A.3.1.3.2 Evaluation of HSP

The Hydrocomp Simulation Program can be applied for the continuous simulation of both water flow and quality in urban and rural watersheds and channel networks. It was originally developed for the hydrologic simulation of rural catchments, and recently water quality computations for natural rivers and impoundments were added. The Stanford Watershed Model, upon which it is based, is perhaps the most detailed and complete, as well as the most used, rainfall/runoff model.

Modifications for urban applications include the addition of separate runoff computations for pervious and impervious areas and flow and water quality routing in circular closed conduits. Other model additions, however, would make the model more generally applicable to urban sewerage systems: for instance, geometries of different closed conduit cross-sections, hydraulic equations for different flow control and diversion structures, formulations for surcharging and pressure flow, and simulation of treatment processes.

HSP has been tested and applied extensively in many non-urban watersheds in the United States and abroad. Comparisons between measured and computed runoff for selected storm events have produced generally good agreement, with some exceptions attributed to potentially unreliable measured data.

HSP is most suited for runoff modeling of urban and non-urban catchments where detailed continuous simulations are required. It is not suited for systems where treatment processes must be simulated or where pressure flow and surcharging are significant factors. Hydrocomp is developing several versions of the basic HSP program for EPA. One of these, the Agricultural Runoff Model (ARM) has been documented (21) and has received limited testing. It may be obtained from U.S. EPA, Environmental Research Laboratory, Athens, Georgia, 30601.

A.3.1.4 MITCAT (Massachusetts Institute of Technology)

The MIT Catchment Model, MITCAT (7), simulates the time-varying runoff of several catchments and a sewer and open channel network including loops and converging and diverging branches. The model is limited to the simulation of single runoff events. Water quality and real-time control features are not included. The MITCAT may be applied to urban or non-urban areas.

The original model was developed at MIT for the U.S. Office of Water Resources Research, but the model has been modified by Resource Analysis, Inc., for routine application.

The MIT urban watershed model includes the following features:

1. Dry-weather flow of several catchments;

2. Air temperature at one weather station;

3. Several rainfall records;

4. Special statistical analyses to compute design hyetographs (separate program);

5. Evapotranspiration;

6. Snow accumulation and melt;

7. Option to choose one of four different infiltration equations;

8. Stormwater runoff from pervious and impervious areas of several catchments;

9. Catchment moisture accounting during periods of no precipitation;

10. Flow routing in gutters;

11. Routing of combined wastewater flow in a converging network of loops and converging and diverging branches;

12. Various standard closed conduits and open channel cross-sections and arbitrary shapes;

13. Downstream flow control, backwater, surcharging and pressure flow;

14. Flow control and diversion structures;

15. Storage facilities;

16. Hydraulic capacities of treatment facilities; and

17. Least-cost sizes of sewers, overflow storage and treatment plants meeting constraints on surcharging and untreated effluent volume (separate program).

The model does not include the following features:

1. Dry-weather flow from land use characteristics;

2. Catchment moisture accounting during periods of no precipitation;

3. Flow reversal;

4. Water quality; and

5. Real-time control.

Dry-weather flow data for each inlet is input in the form of hydrograph values at constant time intervals. The model does not include provisions to compute dry-weather flow from land use.

Several rainfall intensity records can be provided as input data. Not more than one rainfall record can be used to compute runoff from a subcatchment. Special provisions are built into the model to move a rainstorm across a catchment by specifying its direction and velocity of movement. A separate model is available which computes design hyetographs of specified frequencies from measured rainfall data.

Initial losses to fill depression storage on pervious and impervious areas are subtracted before surface runoff begins. The Resource Analysis version has four options to compute infiltration on the pervious areas: Horton's equation, Holtan's equation, a U.S. Soil Conservation Service method, and a runoff coefficient method. Infiltration is subtracted from rainfall if the last two methods are used, but computed from overland flow depth if Horton's or Holtan's equation is used. A method based on filter theory can be used to estimate the infiltration parameters from measured rainfall and runoff. Snowmelt is computed by the Corps of Engineers degree-day method which requires mean daily air temperature as input data. The Penman equation is programmed to compute evaporation but generally not used for single runoff event simulation.

Flow routing is accomplished with the kinematic wave equation. The equations are solved by a finite difference scheme for overland flow, flow in gutters, and flow in open channels (for various standard cross-sections and arbitrarily shaped closed conduits). Downstream flow control and backwater can be considered if the stage-discharge relationship is known. Surcharging and pressure flow is computed separately for each pipe reach. Flow reversal is not modeled. Weir and orifice flow control and diversion structures can be modeled by their hydraulic equations.

The design model computes the sizes and costs of circular sewers, the volumes of overflow storage facilities, and the hydraulic capacities of treatment plants needed to reduce undesirable flooding and surcharging and to eliminate untreated overflows. Linear programming is used to determine the least-cost combination of these facilities for a selected design storm

event. The optimization is based on needed hydraulic capacities alone and does not consider water quality. It requires catchment runoff hydrographs as input data and uses a simplified flow routing scheme.

MITCAT was developed under a series of projects for the U.S. Office of Water Resources Research. Each project covered a different aspect of the overall model development. The computer programs were written for an IBM 360/67 in FORTRAN IV. The design program utilizes the linear programming package of the 1971 IBM Mathematical Programming System Extended (MPSX). The model's core storage requirement is not documented. The potential user has to contract with Resource Analysis, Inc., of Cambridge, Massachusetts, for routine applications of the model.

Computer output of the model includes tables of rainfall intensities and overland, catchment and channel depth, velocity and discharge. Samples of program output are not included in the documentation for the design option but output for this option includes the volume and duration of flooding for each sewer and the required sizes and costs of sewer overflow storage facilities and treatment plants.

A.3.1.4.1 MITCAT Input Data

1. Rainfall data, including velocity and direction of movement;

2. Catchment data, including length, slope, roughness coefficient, infiltration coefficients, detention storage and land use parameters;

3. Stream data, including length, slope, cross-section shape, width/diameter, roughness coefficient, critical conditions;

4. Inflow data;

5. Soil erosion parameters;

6. Storage reservoir data; and

7. Evaporation data.

A.3.1.4.2 Evaluation of MITCAT

The MITCAT is a useful and efficient tool for the simulation of urban and non-urban catchments, including both sewer and natural stream networks where backwater, downstream flow control and surcharging are not important. It is particularly suited where single-event runoff quantity is to be examined. Testing of the model on catchments with drainage areas up to 120 km^2 (46 mi^2) shows good agreement between computed and measured runoff. The model is being used extensively for practical engineering assessments. A major weakness is its lack of water quality calculations, though these are likely to be added at some future date.

A.3.1.5 HVM-QQS (Dorsch Consult)

HVM-QQS, the Quantity-Quality Simulation Program (S) is intended for single event or continuous simulation of the time-varying runoff and water quality in combined sewerage systems consisting of several catchments and a closed conduit and open channel network including loops and converging and diverging branches. Runoff from catchment areas is calculated by a unit hydrograph method, considering different land uses including residential, commercial, industrial, and mixed. The flow routing through the sewerage network is based on the dynamic wave equations. Statistical analyses are incorporated to provide monthly and annual flow and pollutant duration curves for any node in the network. Four conservative water quality constituents can be routed.

HVM-QQS includes the following features:

1. Continuous simulation or single event simulation;

2. Dry-weather flow and quality of several catchments;

3. Three rain records;

4. Stormwater runoff (including quality) from pervious and impervious areas of several catchments;

5. Routing of combined wastewater flow and quality in a network of loops and converging and diverging branches;

6. Various closed conduit and open channel cross sections, (with linearized partial filling curves);

7. Backwater, upstream and downstream flow and quality control, surcharging and pressure flow;

8. Weirs and diversion structures considering both upstream and downstream flow conditions;

9. Pumping stations;

10. Retention storage basins;

11. Wastewater quality improvement at treatment plants and overflow treatment facilities; and

12. Statistical analysis of results.

The model does not include the following features:

1. Snow accumulation and melt;

2. Flow reversal;

3. Detailed flow and quality routing in gutters;

4. real-time control;

5. Sedimentation and scour in channels;

6. Wastewater quality decay, reactions and interactions in sewers and receiving waters; and

7. Design and costs.

The surface runoff from small catchment areas including the flow in street sewers and laterals is obtained by means of a unit hydrograph method which is modified, however, for water quality calculations. The combined consideration of surface runoff and flow in small sewers and the use of a systemized network, each segment of which can be composed of several sewer elements totaling a length of up to 500 m (547 yds), result in a reduction of network nodes. The assumption of linearity of the runoff process, being sufficiently valid for small catchment areas, is not employed for the flow routing through the system of trunk and interceptor sewers, the flow behaviour of which may be influenced by backwater effects and interaction of branching points, retention facilities and overflow structures. Thus, flow routing is based on the dynamic wave equations, which provides the necessary accuracy and still allows for continuous long-time simulation. The hydrographs and flow velocities obtained by the hydraulic calculations form the basis for the pollutant transport within the network. The model is generally applicable to any urban drainage basin and to any pollutant. Presently areas of up to 40,000 ha (100,000 acres) in size can be studied in one run.

Catchment runoff quality formulations currently include biochemical oxygen demand and settleable solids. Formulations are also planned for carbonaceous oxygen demand, suspended solids, coliform bacteria, chloride, and nutrients. The model does not include real-time control, design and cost computations.

HYM-QDS evaluates the quantitative and qualitative loading of up to two receiving waters arbitrarily connected within an urban area. In one run up to four conservative water quality parameters can be taken into

consideration. Three different precipitation records of up to 20 years can enter the calculation, each of which again could be the weighted average of several raingages.

For single event simulation, program output includes both tables and plots of discharges and water quality (mass rates) for any nodal point of the sewerage system and receiving water network. Flow velocities are not printed. For continuous simulation principal output is tables of statistical analysis and graphs of frequency and duration curves.

The computer program consists of a data validation program, a main program and a statistics program which are run sequentially. Model documentation does not describe details of the computer program. This is a proprietary model developed by the engineering consulting firm Dorsch Consult Ingenieurgesellschaft mbH of Munich, Germany (a North American office is maintained in Toronto, Ontario). The model may be released under certain use and distribution restrictions. A user's manual is available upon request.

The complete program package is written in Fortran IV and consists of nearly 30,000 statements. Usable core storage of 400k bytes and a configuration with fast external mass storage are required. The package is presently installed in a Univac 1108 computer. The program, however, can be used on all batch processing systems with Fortran IV compilers.

A.3.1.5.1 HVM-QQS Input Data

Input data requirements for HVM-QQS are extensive, and include:

1. Sewer network data (quite detailed);

2. Precipitation data;

3. Hydrologic data;

4. Dry-weather flow;

5. Input hydrographs;

6. Receiving water geometry and flows;

7. Pollutant accumulation and decay functions; and

8. Storage and treatment facility data.

HVM-QQS has an excellent data validation program which simplifies data management.

A.3.1.5.7 Evaluation of HVM-QQS

HVM-QQS is one of the most complete models for the computation of runoff from urban catchments and the routing of flows in sewer networks. It is potentially the most accurate model for routing flow in sewers, particularly under conditions of surcharge or backwater. Extreme detail with respect to subcatchment discretisation is required, however, to calculate accurate overland flow from rainfall. Simplifications are probably possible to allow larger subcatchment areas without significant loss in accuracy.

The implicit solution of the Saint-Venant equations provides an accurate means of computing the flow routing in the sewers coupled with routing through diversion structures and retention basins. The consideration of both upstream and downstream boundary conditions and the computation of backwater is part of the basic equations and does not have to rely on approximate methods such as those included in some kinematic wave or storage routing techniques. The implicit solution of the Saint-Venant equations coupled with diversion equations is complicated, however, and time consuming on the computer as compared to more approximate methods. To simplify the solution somewhat an iterative scheme is used which cannot consider flow reversal (although it is contained in the basic equations).

Although the model formulations are considerably more precise than most tested models, the increased accuracy demands a sacrifice in computer time. The model would be needed primarily where backwater, downstream flow control, diversion structures, retention basins, and surcharging are important features of the sewerage system assessment. If these features are not present or are considered insignificant, simpler models requiring less computer time can be used.

The model has been applied extensively in Germany and Switzerland, and moderately in Canada, the U.S.A. and other countries. Model comparisons with measured runoff data are limited.

HYM-QQS has been verified checking quality against measurements taken in Augsburg, Munich and Stuttgart, Germany, and quantity against the Dorsch Consult HYM-Method and measurements. The model presently is applied to Augsburg, Germany (360,000 inhabitants), and to Rochester, New York. Documentation of the model is not generally available.

A.3.1.6 Metcalf and Eddy Model

The Metcalf and Eddy Model (9) is the simplest of the models evaluated, and is intended as a planning tool to gain some insight into the system under study and to aid in the initial screening of alternatives. It provides a very easy, direct methodology, divided into three subsystems. The first, rainfall characterization, is a sorting and analysis of rainfall data from local records. Operating directly from Weather Bureau tapes or published summaries, long periods of record can be easily analysed, and the arrayed output allows historical classification of rainfall. The second, storage-treatment balance, uses historical rainfall data, converted to runoff by coefficient which is stored in a special volume which is emptied at a specified rate. When runoff exceeds the combined storage-treatment rates, changes in overflow occurrence and duration can be examined. The third, discharge-receiving water response, applies pollutant concentrations to overflow volumes to determine pollutant mass loadings. Several methods for arriving at pollutant concentrations are suggested. Receiving water

response is analysed separately.

The Metcalf and Eddy Model includes the following features:

1. Analysis of long-term records;

2. Simple, direct calculations;

3. Quality and quantity calculations;

4. Modular, to allow user to select only components he needs; and

5. Allows incorporation of probability in a simple fashions.

The model does not include:

1. Dry-weather flow;

2. Conduit flows; and

3. Costs or design capability.

The computer program, or rather programs, are written in FORTRAN IV, and can be run on virtually any size computer with a FORTRAN IV compiler. Computer program is available from EPA along with the documentation.

A.3.1.6.1 Input Data for Metcalf and Eddy Model

1. Rainfall-program will process Weather Bureau hourly or daily summaries;

2. Sewer system schematic (while not required by the program, essential to understanding system) including overflows and their associated drainage areas and pertinent interceptor capacities;

3. Runoff coefficient;

4. Pollutant concentrations; and

5. Storage capacity and treatment rate.

A.3.1.6.2 Evaluation of Metcalf and Eddy Model

This simple model is an invaluable tool for preliminary analysis. It is particularly useful for rainfall-runoff probability determination, and to get rough first-cut evaluations of storage-treatment alternatives. It is straightforward and inexpensive, and will allow engineers and planners to quickly gain an insight into their local problems, and to determine where more detailed models are required. The model has been applied extensively by Metcalf and Eddy, and is presently being used on an EPA project in Rochester, New York (See Chapter 3 for additional details of this model application in preliminary screening applications).

A.3.1.7 AGRUN (Water Resources Engineers)

AGRUN (10) is a revised version of the RUNOFF block of the Stormwater Management Model (SWMM) which can be used to estimate runoff quantity and quality from agricultural lands. It is included in this list as an example of a model that is useful in rural or semi-rural portions of the 208 area. AGRUN has not been extensively tested, and potential users are cautioned accordingly.

The changes made in the SWMM RUNOFF block to create AGRUN include:

1. The capability to route pollutants through as many as 200 tributary channels. The tributary system must be dendritic. Channel cross sections may be triangular, trapezoidal or rectangular;

2. The capability to model up to 22 quality constituents (only total suspended solids, BOD and fecal coliforms have been verified). The Universal Soil Loss equation is used to compute suspended solids sources loading rates. Source loading rates of other pollutants is assumed directly proportional to the solids loading rate, the proportionality constant being a function of land use type; and

3. The capability to simulate interflow contributions to runoff. Up to five layers of soils are handled on each subarea. Each layer is assumed to be of uniform thickness and parallel to the surface. A planar, impermeable boundary exists at the bottom of the lowest layer.

The computer program is written in FORTRAN V, the program and associated documentation are available from EPA, Office of Water and Hazardous Materials, Washington, D. C. 20460.

A.3.1.7.1 Input Data for AGRUN

In addition to the data required by the normal RUNOFF block, AGRUN requires:

1. Channel specifications;

2. Land use hydrodynamics data;

3. Crop types; and

4. Baseflow data.

A.3.1.7.2 Evaluation of AGRUN

This model, though relatively untested, should prove useful for detailed examination of rural or semi-rural runoff. It may be linked to the SWMM to

evaluate such things as storage-treatment options or impacts on receiving water quality. Use of this model should be undertaken by personnel familiar with the basic SWMM.

A.3.1.8 ILLUDAS (Illinois State Water Survey)

The Illinois State Water Survey Urban Drainage Area Simulator (ILLUDAS) (11) was developed by the Illinois State Water Survey for single-event simulation of time-varying runoff in combined sewerage systems consisting of several catchments and a converging sewer and open channel network. The model is based on a computer version of the British Road Research Laboratory Model, but computes also the runoff from pervious areas and includes the option to size either circular sewers or retention basins. The design option is based on hydraulic considerations alone and does not consider costs. Water quality is not modeled.

ILLUDAS will accept a specified storm, or will distribute, according to user specified parameters, a given total rainfall volume. Equal time increments of rainfall are applied to sub-basin of the total urban basin. A computation is made of the travel time required for each increment of runoff to reach the inlets at the downstream end of the sub-basin. In this way a surface hydrograph is provided for each sub-basin. These surface hydrographs from each sub-basin are accumulated in downstream order through the basin. This accumulation of inflow hydrographs is routed through each section of pipe to account for the temporary storage within each pipe section. The result is a computed outflow hydrograph from each section of pipe, and ultimately a hydrograph at the outlet of the total basin.

Infiltration is calculated using Horton's method and provision is made for satisfying depression storage before infiltration takes place. Detention storage may be handled in two ways. If the user specifies a detention volume at some point in the basin, ILLUDAS will utilize that storage and report the resulting decrease in peak flow. If on the other hand the user wishes to limit the peak flow at some point, ILLUDAS will report the storage volume required to reduce the peak flow to the desired rate.

ILLUDAS is available from the Illinois State Water Survey in the form of a Fortran IV deck of some 800 cards. About 150 K bytes of core are required. The program was developed for use on an IBM 360-75 and is available only in that form. The output format is presently best suited to a 130 space line but work is underway to develop a 72 space format for use on remote terminals. ILLUDAS is available commercially on the McDonnell Douglas Automation Company (MCAUTO) system in St. Louis.

A.3.1.8.1 Input Data for ILLUDAS

1. Precipitation data

2. Paved and grassed areas and their slopes

3. Hydrologic soil groups

4. Paved and grassed area abstractions.

5. Sewer length, slope, shape, Manning's "n".

6. Available storage.

A.3.1.8.2 Evaluation of ILLUDAS

ILLUDAS has been extensively tested and used, and the program is well documented. It has some sewer design capability and should be useful in the analysis of runoff-storage analyses. The Illinois State Water Survey provides training courses in application of the model. It is most useful where single rainfall events are to be simulated and water quality is not a consideration.

A.4 Water Quality Models

Water quality models are the most important, and in many ways least understood, link in the chain of models for environmental assessment. The

physical, chemical and biological phenomena represented by the models are very complex, and many simplifying assumptions must be made by the user in the course of model development and application. More specialized technical skill is required in the use of water quality models than of any other type. In fact, it is essential that a person skilled in the water quality area be available for input preparation and interpretation of results. The comments regarding default values outlined in section A.3 are equally applicable here.

The models listed in this section (see Table A-2) meet the criteria of being generally available, well-documented and have been tested and applied. They also demonstrate a range of models available to the user. Previously (A.2) it was indicated that a careful investigation should be undertaken to identify models in local use. This is particularly true with water quality models. While the user will have to assure himself that the model has been correctly formulated and properly verified, a water quality model, even a relatively simple one, that is in use in the local area and for which data have been gathered will prove invaluable and may make it the overriding model of choice, particularly where resources are limited.

In general, it is better to examine a limited number of quality constituents in a water quality modeling exercise, even though the model may be formulated to accomodate a broad spectrum. This will simplify the problem of data acquisition, make the model easier and cheaper to use and simplify the analysis of results.

A.4.1 Water Quality Models

A.4.1.1 DOSAG-1 (EPA)

DOSAG-1 (12), developed originally by a predecessor agency of EPA and modified by the Texas Water Development Board, and now disseminated by EPA, Office of Water and Hazardous Materials, uses the classical Streeter-Phelps DO sag equation, modified to include nitrogenous biochemical oxygen demand to simulate DO and BOD variations. It is a steady-state model, suitable

TABLE A-2 WATER QUALITY MODELS

Model Origin	Acronym	Water Bodies Modeled[1]			Time Variability		Spatial Discretization			Miscellaneous			Constituents Modeled
		Stream	Estuary	Lake	Steady-State	Dynamic	One-Dimensional	Two-Dimensional	Stratified	Documentation Available	Computer Program Available	Applied to Real Problems	
Environmental Prot. Agency	[illegible]	●			●		●			●	●	●	[illegible] (Carbonaceous and nitrogenous)
EPA	[illegible]	●			●[2]		●			●	●	●	[illegible], [illegible], temperature, [illegible], [illegible], [illegible], algae, phosphorus, benthic demand, coliforms, radioactive materials, 3 conservative constituents.
EPA	[illegible]	●	●			●		●		●	●	●	Any six constituents, including [illegible], [illegible], conservative constituents and non-conservative constituents with first order decay.
Raytheon (EPA)	[illegible]	●	●			●		●		●	●	●	[illegible], [illegible], coliforms, nutrients, salinity, conservative constituents, non-conservative constituents with first order decay, chlorophyll a.
Systems Control Inc.	[illegible]	●	●			●		●		●	●	●	[illegible], [illegible], coliforms, excess temperature, [illegible], [illegible], [illegible], [illegible], Cu, Pb, and two conservatives.
Water Resources Engineers (EPA)	[illegible]	●	●			●		●		●	●		[illegible] (linked), any four conservative or first order non-conservative.
Hydrocomp, Inc.	[illegible]	●		●		●		●	●	●	[3]	●	[illegible], [illegible], coliforms, temperature, algae, zooplankton, sediment, organic nitrogen, nutrients and conservative constituents.
Office of Water Resources Research	[illegible]			●		●	●		●	●	●	●	Zooplankton, benthic animals, fish, pH, nutrients, conservative constituents, non-conservative constituents with first order decay.

1. Stream models can simulate shallow, well-mixed impoundments.
2. Weather inputs may be dynamic.
3. Available for a fee.

for modeling non-estuarine streams with no reservoirs. The model is constrained in that no more than than 10 headwaters, 20 junctions, 20 stretches (sections between junctions) and 50 reaches may be modeled.

DOSAG-1 is capable of calculating flow augmentations needed to maintain DO at a prescribed level, and of determining dissolved oxygen distribution for varying levels of treatment (waste treatment plants) in the simulated river basin. Computations are performed on a reach-by-reach basis. DOSAG-1 calculates the time required for a particle of water to travel downstream to the first lateral inflow (tributary, outfall, etc.) to the stream. The changes in the concentration of constituents which would occur during the travel time are computed and the concentrations of constituents adjusted accordingly. These adjusted concentrations represent the stream quality just above the lateral inflow. The inflowing water quantity and wasteload are then added to those of the stream, resulting in a new stream flow and a new value for the concentration of constituents in the stream at the point of inflow. The program then calculates how long it would take a particle of water to travel downstream from that point to the next lateral inflow, and the whole process is repeated. All temperature-dependent parameters are adjusted on a reach-by-reach basis during the computations.

The computational procedure is repeated on each headwater stretch downstream to the first junction, and then proceeds downstream throughout the system until the water quality constituent concentrations are determined for the entire stream system. No diffusion or stratification is modeled and at any point the stream is assumed to be uniformly mixed.

All inflow rates and all constituent concentrations in the inflows are specified by the user. The temperature of each reach is also user specified. Withdrawal of water from the stream system is modeled by specifying a negative inflow at that point.

A.4.1.1.1 DOSAG-1 Input Data

Input data required for DOSAG-1 is relatively simple and straightforward. It includes:

1. Flow rates for system inputs and withdrawals;

2. Information on reaches, junctions, stretches, headwater reaches;

3. Reaction coefficients;

4. Concentrations of inflows; and

5. Stream temperature.

A.4.1.1.2 Evaluation of DOSAG-1

DOSAG-1 is a simple, well-tested, frequently used model which can predict stream DO concentrations with relative accuracy. The model has been modified by others (13), and has good documentation. The computer program is simple enough that repeated program runs may be made at low cost once initial set-up has been done. It is most useful where DO considerations control water quality, and where steady-state conditions apply.

A.4.1.2 QUAL-II (EPA)

QUAL-II (14), developed by Water Resources Engineers as a modification to QUAL-I (15), is a quasi-dynamic stream model. It will simulate both steady-state stream flow and the steady-state and dynamic behavior of the following constituents:

1. Chlorophyll-a;

2. Nitrogen;

Ammonia

Nitrite

Nitrate

3. Phosphorus;

4. Carbonaceous BOD;

5. Benthic oxygen demand;

6. DO;

7. Coliforms; and

8. Conservative substances.

QUAL-II is constrained in that no more than 15 headwaters, 15 junctions, 45 reaches and a total of not more than 45 input/withdrawal elements can be modeled.

QUAL-II numerically integrates, using a wholly implicit numerical scheme, the advection-dispersion mass transport equation for all water quality constituents to be modeled. The equations include the effects of constituent reactions and interactions, and a source term.

QUAL-II is applied by subdividing the stream system into reaches (stretches of stream with uniform hydraulic characteristics). Each reach is then divided into computational elements of equal length, so that all computational elements in all reaches are the same length (Max. of 20 computational elements per reach).

The computer program is written in Fortran IV for the IBM 360/370 series computers. It is structured as one main program supported by 20

subroutines. This allows changes in parameters or modification of parameter relationships with a minimum of model restructuring

A.4.1.2.1 QUAL-II Input Data

The input data required by QUAL-II include:

1. Identification and description of stream reaches.

2. Initial conditions.

3. Hydraulic coefficients for determining velocity and depth.

4. Reaction coefficients.

5. Junction data.

6. Headwater data.

7. Waste loadings and runoff conditions.

8. If temperature is to be modeled, also requires sky cover, wet bulb/dry bulb air temperature, atmospheric pressure, wind speed, evaporation coefficient, and basin elevation.

A.4.1.2.2 Evaluation of QUAL-II

QUAL-II is a simple model, which has been extensively tested and used. Application of QUAL-II requires less resource expenditure than any of the computer models listed herein except DOSAG-1. QUAL-II is disseminated without cost by EPA, Office of Water and Hazardous Materials, Washington, D.C. The model, given valid input data, will reliably predict water quality with a relatively high degree of accuracy. QUAL-II is most suited to situations where several water quality constituents are to be modeled and where steady-state streamflow calculations are appropriate.

A.4.1.3 RECEIV (EPA)

RECEIV, originally developed as a part of the EPA Stormwater Management Model (SWMM) (4,5), is suitable for modeling estuaries and streams, and may be also used to model lakes if one can assume they are relatively shallow and well-mixed. RECEIV represents the water body with a network of nodal points connected by channels. The nodal points and channels are idealized hydraulic elements which are characterized by parameters such as surface area, cross-sectional area, length and friction coefficient. The equations of motion and continuity are applied to each element and solved simultaneously to produce a true history of stage, velocity and flow at the various points of the receiving water system. The model is not suited for modeling highly stratified water bodies. RECEIV has the capability of simulating tidal flats (surface area need not be constant) and will handle tidal boundary conditions at multiple seaward boundary locations. RECEIV will accept transient inputs, such as storm water inflow, and is useful in examining the effects of various upstream treatment schemes with different removal rates in that several water quality simulations may be performed for a given quantity simulation. Water quantity simulations may be performed separately from, or together with, quality simulations. The model will accomodate up to six conservative quality parameters and non-conservative parameters with first-order decay. When BOD is modeled, its influence on DO is calculated and resulting DO levels are determined simultaneously. The model assumes an advective transport mechanism, and does not accomodate diffusion transport. RECEIV computes concentrations of pollutants on incoming tides using a seaward exchange coefficient, and models these concentrations as a constant value during the tidal cycle. RECEIV is programmed in FORTRAN IV.

A.4.1.3.1 RECEIV Input Data

RECEIV requires fairly extensive input data, which includes:

1. Tidal variations

2. Water surface elevations, area and depth

3. Bottom roughness coefficients

4. Meteorological data, including rainfall, evaporation, wind velocity and direction

5. Downstream boundary conditions

6. Junction and channel data

7. Water temperature

8. Initial pollutant concentrations

9. Inflow data

10. Oxygen saturation and reaeration coefficients

A.4.1.3.2 Evaluation of RECEIV

RECEIV is a relatively complex model which is most applicable to estuaries and which has been extensively used. Considerable skill is required to apply it effectively, and the documentation, while adequate, is not as good as documentation for the rest of the SWMM. There are many variants of RECEIV, several of which will be subsequently described. The program and its documentation are available without charge from EPA, Office of Research and Development (RD-682). RECEIV is most applicable when SWMM is being used, and its main strength, as with SWMM lies in the continuing maintenance, improvement and documentation that is taking place.

A.4.1.4 RECEIV-II (RAYTHEON/EPA)

RECEIV-II (16) was developed by Raytheon, under contract to the Water Planning Division, EPA, and is a modification and expansion of the RECEIV

model in SWMM. RECEIV-II preserves the compatibility with the original SWMM coding through a new subroutine called SETUP. The other major differences between RECEIV-II and RECEIV are in the water quality constituents modeled and the relationships describing the behavior of those constituents. RECEIV-II simulates eleven (11) water quality constituents, including the nitrogen cycle, phosphororus, chlorophyll-a and salinity, in addition to BOD, DO and coliforms. Included are representations of the biological and chemical linkages between constituents. An important feature is the ability to compute constituent concentrations downstream of a dam, by adjusting DO reaeration due to spillage over the dam. RECEIV-II is programmed in ANSI Standard FORTRAN for both IBM and CDC computers.

A.4.1.4.1 RECEIV-II Input Data

Input data requirements for RECEIV-II are essentially the same as those for RECEIV, except in the SETUP block, which requires more detailed specification of boundary conditions, and in specifying initial pollutant concentrations and reaction coefficients because of the larger number of pollutants modeled.

A.4.1.4.2 Evaluation of RECEIV-II

RECEIV-II has been extensively tested, and has been applied to a number of receiving waters. The documentation is excellent. In fact, it is desirable for a user of RECEIV or any of its variants to have a copy of this documentation, since it gives a much better description of the theory and application than is provided in SWMM documentation. It is only slightly less convenient to use with the SWMM than RECEIV, and will probably give better results, since a number of errors in RECEIV were corrected in the development of RECEIV-II. The program and documentation are available without charge from EPA, Office of Water and Hazardous Materials, or at nominal cost from Raytheon Corporation.

A.4.1.5 SRMSCI (Systems Control Inc.)

SRMSCI, developed by Systems Control, Inc. (13), is another variant of the RECEIV block of SMMI. The principal modification is the addition of the capability to model excess temperature, the nitrogen cycle, phosphorus, lead, and copper. The nutrient-algae cycle and second-order decay of nitrogen or phosphorus are accomodated. In other respects, SRMSCI is the same as RECEIV.

A.4.1.5.1 SRMSCI Input Data

Input data requirirements for SRMSCI are the same as for RECEIV, except that more pollutant data (intial concentrations, decay rates) are required.

A.4.1.5.2 Evaluation of SRMSCI

SRMSCI is well-tested and documented, but has not been as extensively used as RECEIV or RECEIV-II. It should provide results comparable to either model. The program and documentation are available at nominal cost from the Snohomish County Planning Department, Everett, Washington, or Systems Control, Inc.

A.4.1.6 WRECEV (Water RESOURCES Engineers)

WRECEV (17) is yet another modification to the RECEIV block in SMMI, and, like its predecessor has a hydrodynamic module and a quality module. It was developed to increase the applicability of the basic RECEIV to streams.

The following revisions were made in the hydrodynamic module:

1. Modify geometric specifications of channel and junctions;

2. Solve the finite difference form of the equation of motion for flow rate;

3. Allow constant inflows, constant withdrawals and variable flow hydrographs to occur simultaneously at any junction;

4. Use logical variables in the computer code where possible;

5. Reduce core requirements for model execution;

6. Permit execution with no interface units if desired; and

7. Restructure input data requirements.

The following revisions were made in the water quality module:

1. Allow constant inflows, constant withdrawals and variable flow hydrographs to occur simultaneously at any junction.

2. Allow time-variant inflow concentrations of all simulated constituents.

3. Input temperature to allow internal temperature correction for any input reaction rates and internal computation of DO saturation concentration.

4. Include five-day BOD as an optional constituent.

5. Allow spatial variation of any input reaction rates.

6. Compute the reaeration coefficient at each time step.

7. Include the effects of dispersion in the computations.

8. Revise advection computations.

9. Insert warning messages to indicate that the advection ratio criterion has been violated.

10. Restructure input data requirements.

These changes have resulted in making the model easier to use and requiring less computer time for execution. WRECEV has been designed for use either as a stand-alone module or with a direct linkage to SWMM. WRECEV is programmed in FORTRAN IV.

A.4.1.6.1 WRECEV Input Data

Input data requirements for WRECEV are essentially the same as those for RECEIV. The documentation, however, provides a much clearer description of input formats and the data input process.

A.4.1.6.2 Evaluation of WRECEV

WRECEV is relatively new and untried, but is based on considerable experience with RECEIV and should hence perform at least as well. The documentation is excellent, and the reader would, as with RECEIV-II, be well advised to obtain a copy if he plans to use any variant of RECEIV. WRECEV is available without cost from EPA, Office of Water and Hazardous Materials.

A.4.1.7 IWQM (Hydrocomp, Inc.)

The Hydrocomp Water Quality Model (IS) is applicable to non-tidal receiving waters. It is a dynamic model simulating a number of water quality indices, including temperature, total dissolved solids (TDS), DO, BOD, coliforms, algae-chlorophyll-a, zooplankton, nitrogen, ortho-phosphate and condensed phosphate, and conservative constituents such as metals and chlorides.

In IWQM a stream system is divided into reaches, assuming complete mixing in each reach. During each time step, the transfer of water into and out of each reach is determined and the chemical and biological processes computed. Impoundments are considered similarly to stream reaches, except

that stratification may be analysed by assuming the impoundment consists of three layers and that mixing occurs between layers. The mixing coefficient (fraction of one layer mixed with another layer) is a function of time of year to approximate various mixing phenomena that occur. Diffusion is not modeled. IWQM is set up for direct linkage to HSP (see A.3.1.3) which will provide surface runoff inputs to the receiving water. IWQM is programmed in PL1.

A.4.1.7.1 IWQM Input Data

The input data requirements for IWQM are extensive, but a library program module is available (as in HSP) which considerably simplifies the management of this data. Input data includes:

1. Watershed data, including descriptions of reaches and lakes;

2. Reaction coefficients;

3. Initial conditions of flow and pollutant concentrations;

4. Temperature data; and

5. Data on quantity and quality of inflows.

A.4.1.7.2 Evaluation of IWQM

IWQM has not been extensively tested or applied, however it may be expected to give good results. It is a proprietary model, available only from Hydrocomp on several fee bases. Training courses in its application are conducted by Hydrocomp. It is the most complex of the water quality models reviewed here and requires considerable expertise in the water quality area. The documentation is adequate, and available from Hydrocomp for a fee.

A.4.1.8 LAKECO (OWRR)

The Lake Ecologic Model (LAKECO)(19) developed by Water Resources Engineers for the Office of Water Resources Research (OWRR) is a dynamic model for simulating water quality and biological populations in stratified lakes. LAKECO is primarily a tool to aid the user in determing the effects on the water quality and temperature of a lake due to meteorological changes or to changes in the flow rate, temperature, and/or concentrations of the lake inflows or the flow rate and/or positions of the lake outflows. The model may also be used to predict conditions in lakes yet to be formed and to aid designers of impoundments.

It has substantially greater capability than the Deep Reservoir Model from which it was derived. LAKECO carries out most of its hydrodynamic calculations simultaneously with its water quality calculations. LAKECO models TDS, the DO budget, nutrient cycles, coliform and algal life processes, benthal demands and releases, temperature, pH, the detritus cycle, and zooplankton and fish cycles. A total of nineteen non-conservatives and two conservatives may be modeled. The lake being modeled must be represented by less than 100 horizontal layers. A maximum of ten inflows and ten outlets are permitted.

Computations performed by LAKECO include consideration of stratification, dilution, diffusion, advection, settling, mass addition, decay, growth, benthal releases, internal coupling between constituents, reaeration, respiration, mortality, photosynthesis, short wave radiation, wet and dry bulb air temperature and wind.

LAKECO calculates the concentration profiles of the lake being modeled in the following manner: The lake is considered to be divided into a number of horizontal layers. The lake inflow is distributed into the appropriate layers from consideration of temperatures, flow rate, and layer volumes. The lake outflow is withdrawn from the appropriate layers from consideration of outlet location(s), flow rate, and layer volumes. Transports between layers are computed.

The concentration and/or temperature changes in each layer due to factors listed above are then calculated and the concentrations are updated. The temperature and concentrations of the outflows are also calculated for the time step. The procedure is continued until the end of the simulation period is reached, at which time a complete history of the temperature and concentrations in each lake layer and in the lake outflows have been generated. All temperature-dependent parameters are adjusted on a layer by layer basis during the computations. LAKECO is written in FORTRAN IV.

A.4.1.8.1 LAKECO Input Data

Input data requirements for LAKECO are fairly extensive, and include:

1. Meteorologic data, including sky cover, wet/dry-bulb temperature, wind speed and direction, atmospheric pressure;

2. Lake latitude and longitude;

3. Flow rate of lake inflows (steady-state or time varying) during the simulation period;

4. Table defining surface area and volume as functions of depth;

5. Outlet locations;

6. Concentrations (steady-state or time varying) in the lake inflows of all quality constituents (including temperature) being modeled for the simulated time period;

7. All reaction and decay rate constants for each lake layer, including growth rates, mortality rates, respiration rates and settling velocities;

8. Extinction coefficient;

9. Diffusion coefficients;

10. Temperature stability coefficient; and

11. Initial concentrations for the simulation period of all constituents (including temperature) for each layer.

A.4.1.8.2 Evaluation of LAKECO

LAKECO has been extensively tested and applied, and can be expected to give good results, though it is rather complex. Application of LAKECO would provide an adequate picture of an annual lake cycle, but not long-term trends toward eutrophication. The program and documentation are available at nominal cost from CWRR.

A.5 Typical Model Selection Approach

In the application of models in a typical 208 study, the following sequence is suggested.

1. Define the objective - have a clear statement of what the study objectives are. This is, unquestionably, the single most important step in the process, and probably the most difficult. Time spent here, however, will be compensated by the fact that a clear objective will make all subsequent tasks simpler. The objective should be specific, and describe clearly what the study is to accomplish. A study objective such as "develop a 208 plan to satisfy PL 92-500" is vague and subject to a variety of interpretations. If it were refined to read "determine the relative impacts of nonpoint discharges and combined sewer overflows in the 208 area to other point sources in that area with respect to 7-day, 10-year low flow standards, assuming that

upstream loadings will not change," it is much more likely that all parties will have the same understanding. The selection of an appropriate methodology will be much easier, and the study results are more likely to address the real problems.

2. Gather and assess available information - at this stage the requirement is to identify what already exists and where it is located. Data on land use, population, precipitation, streamflow, point discharges, the local sewerage system, etc. should be gathered. The results of any previous studies or on-going work (201 plans, university research projects, 303 (e) plans) should be analyzed to get a feel for the local situation and a better idea of what direction the study should take. Almost every area has had some work done, and time spent locating and evaluating available information can reduce duration and costs of current work. Local expertise familiar with the area under study may be identified, and can become an important part of the study team.

3. Apply some simple model (may or may not be a computer model) to get some idea of how the areawide system you now have behaves, and the relative influence of various pollutant sources - large systems are complex, and intuitive judgements about their behavior may be totally inadequate. By using a simple model, the planner can "play" with his system easily and cheaply and get some feel for the response of the system to various alternatives. This step can also point up shortcomings in the existing data base, and provide valuable insight into more detailed analyses that may be required. Chapters 2 and 3 provide more discussion on this subject.

4. Determine if more detailed modeling is necessary, and if so, where - remember the study objectives, and use only the tools needed to achieve those objectives. The models described herein cover a broad range of capabilities, and in general, the more complex the model, the more resources required for its application. Do not,

however, assume that increased sophistication and resolution necessarily imply increased accuracy or utility. Many 208 planning studies have started with the assumption that a specific model would be applied, and then the rest of the planning was done to fit that assumption. Models are not simple to apply, and the pre-selection of a model without a feel for the problem to be investigated is sure to result in wasted time and effort. The only possible exception is where there is a model already installed and calibrated for an area.

5. Gather data and apply selected models - it is at this point that data for model calibration and verification is collected, if it is not already available. Again, the study objectives must be kept firmly in mind, and only that data gathered which is necessary. Model application should follow procedures outlined in pertinent model documentation. Models applied at this stage will probably be utilized during subsequent studies or in on-going planning, so thorough documentation of the model application should be prepared. If this is not done, continuity is easily lost, and a costly tool will be wasted.

6. Evaluate results and determine future requirements - the results of the modeling should be reviewed to see if study objectives have been met. If further data is required, or if other alternatives are to be analysed, step 3 may need to be repeated.

A.6 Sources of Assistance:

There are often many sources of assistance available locally to the user. These include:

1. Universities - They may be doing modeling or data-gathering which would be useful, and may even have an operating model which would serve for planning purposes. Departments of Biology, Ecology,

Water Resources, etc., may be involved as well as engineering departments.

2. Agencies - State and Federal agencies have sponsored a great deal of work, and some of it may be useful in your area. Federal agencies which do environmentally-related modeling or have sponsored such work include:

   a. U.S. Environmental Protection Agency - Office of Research and Development, (RD-682) and the Water Planning Division (WH-554).

   b. U.S. Geological Survey - They also have a data-gathering program.

   c. Soil Conservation Service (USDA).

   d. U.S. Army Corps of Engineers Hydrologic Engineering Center.

   e. Office of Water Resources Research.

3. Consultants - There are a number of consultants specialized in urban drainage and/or water quality modeling. Even though they may not be your primary consultant, they are very useful for review of your program for model application and calibration, or of results obtained.

4. Service Bureaus - Most of the models listed are available on some regional or national service bureau, such as McDonnell Automation, CDC, Service Bureau Corp., University City Science Center, etc. If not, a service bureau will often accept the responsibility for model setup in return for using their system. Some even have personnel familiar with model applications to offer assistance.

5. Training Courses - A number of training courses are offered which are useful to model users. They include:

   a. Short courses in storm water model application offered by U.S. EPA and by the Ontario Ministry of the Environment, Canada.

   b. 208 seminars conducted nation-wide, and sponsored by EPA's Water Planning Division and the Regional offices.

   c. ILLUDAS training course offered by the Illinois State Water Survey.

   d. Urban runoff seminars sponsored by the American Public Works Association (APWA).

   e. HSP seminars presented by Hydrocomp, Inc.

6. 201 Planning/Design - In many areas wastewater treatment facilities are being or have been analyzed or designed, and much information is available from these studies. Regrettably, there are instances when jurisdictional problems or a lack of communication have resulted in a failure to pool information.

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APPENDIX C
LAND USE DATA COLLECTION AND ANALYSIS

C.1 Introduction

As mentioned in Chapter 2 of this Areawide Assessment Procedures Manual, land use considerations are extremely important in the development of areawide water quality management programs. Land use projections relate directly to the projection of future waste loads generated by both point and nonpoint sources. In this regard, the physical characteristics of the land surface, e.g., soils, slope, vegetative cover, etc., are reflected in the waste loads that may be anticipated to originate from different land use categories such as cropland, forests, etc. Similarly, activities associated with the land surface also are directly related to the potential waste loads generated. Thus a heavily industrialized parcel will likely be associated with a different set of water quality problems than a residential area or an area under intensive cultivation.

Although the state-of-the-art in precisely identifying the relationship between land use and water quality is not highly developed, this Appendix is designed to provide a description of a range of land use and demographic data collection, management, and analysis techniques.[1] It is hoped that the "menu" of alternatives summarized herein will be of practical use to 208 planners confronting land use/water quality-related issues in the formulation and evaluation of alternative water quality management plans.

C.1.1 Objectives and Scope

The overall objective of Appendix C is to describe a range of specific techniques and qualitative considerations for land use data collection, management, and analysis in areawide water quality management planning. More specifically, this Appendix is designed to provide 208 planners with a

description of:

1. The range of potential land use data needs for 208 planning
2. The available sources of potentially useful land use data (Federal, state, and local)
3. The potentially applicable techniques for land use data collection
4. The alternative approaches to land use data management
5. The potentially applicable techniques for demographic and land use data analysis and projection.

In the discussion of each of the above topics, the objective is to provide the planner with a descriptive survey of alternative approaches to the land use element of the 208 planning process, from relatively simple techniques to complex ones. It should be emphasized that this Appendix is not meant to be prescriptive, but rather an inventory of alternative approaches that will assist the practitioner in selecting appropriate methods to meet his or her specific needs and objectives relative to the land use element of 208.

It should be noted that this Appendix does not address the issue of potentially applicable land use controls that might be considered in the 208 program. Instead, it focuses on the definition of water quality problems relative to land use, and how alternative projected land use configurations and waste loads might be evaluated. In this respect, the land use material discussed here must be utilized in conjunction with the other 208-related areawide assessment procedures outlined in other sections of this Manual, particularly the approaches to regional water quality assessment.

C.1.2 Relationship of Appendix C to Other Portions of the Areawide Assessment Procedures Manual

As the title of Appendix C suggests, it is designed to provide the 208 planner with information concerning alternative approaches to completing the land use element of the 208 program. In order to be effective, however, the land use element must be prepared in a manner that facilitates its use for point and nonpoint source evaluation and control in both urban and non-urban settings. Thus, the material on land use data collection and analysis

contained in Appendix C is a key input to several other portions of the 208 planning process. More specifically, the land use element is related to the following important aspects of areawide water quality management planning:

1. Identification of existing point and nonpoint source loads (including those associated with agriculture, silviculture, construction and mining activities, etc.)
2. Projection and quantification of future pollutant loadings from both point and nonpoint sources.

Thus the land use data collected are an important input to the water quality analysis portion of the 208 planning process, which commonly includes a modeling effort. The alternative land use data collection and analysis techniques outlined in this Appendix must be adapted to the specific procedures chosen for the assessment of pollutant sources and loadings for both urban and non-urban areas. This requires a sensitivity on the part of the practitioner to the need for consistency between the land use information that results from the various analytical approaches, and the input data required to apply to the particular water quality assessment approach chosen. This Appendix presents various land use evaluation techniques that can provide different levels of sophistication in terms of analytical input for the various levels and methods of pollutant loading estimation presented in Chapters 2 through 4 of this Manual.

C.2 Identification of Land Use Data Needs

This section summarizes the types of land use data that 208 planners need to consider as they relate land use issues to water quality management. Since most 208 planning regions have had experience with land use programs of other sorts, the first subsection outlines some data requirements of more traditional land use planning efforts. Next the range of land use data needs for the 208 program is identified. Finally, the more traditional land use planning program data needs are compared and contrasted with those of the 208 program. This comparison is designed to put into perspective the land use element of 208 in terms of more traditional land use programs from which designated 208 agencies will want to extract as much relevant data as possible. Information on the wide range of potentially relevant Federal

and EPA programs is found in the information matrices entitled "Selected Federal Programs Related to Regional Planning", and "EPA Programs Related to State, Regional, and Local Planning". These matrices are included in the pocket at the end of this Appendix.

C.2.1 Traditional Land Use Planning Data Needs

Traditional land use planning or comprehensive planning has dealt with a broad range of development issues at the regional level - all of which relate to some extent to the scope of the 208 planning program. The scope of regional comprehensive planning commonly encompasses the following topics:

1. Physical land characteristics, e.g., soils, slope, vegetation, available minerals, etc.
2. Demographic trends translated into demand for housing, employment, and various services, e.g., power, water, sewer, police and fire protection, etc.
3. Future land use configurations in the context of meeting anticipated demands while avoiding nonconforming uses, inefficient development patterns in terms of the provision of needed services, etc.
4. Transportation considerations that influence, and are influenced by, potential land use development trends
5. Recreation demand, and the provision of sufficient facilities, and open space to meet anticipated demands.

Each of the above topics involves the collection and analysis of various types of data in the traditional land use planning program. These data need categories are summarized as follows:

1. Soils information including soil type, development class limitations, bearing capacity, etc.
2. Vegetation classes including cropland, forest associations, barren land, etc.
3. Population growth trends by political subdivisions
4. Baseline data on housing availability by type, employment categories, etc.
5. Identification of existing land uses by land use category,

e.g., single family residential, multi-family residential, industrial (light and heavy), commercial, transportation, etc.

6. Inventory of existing and projected service areas for water and sewer services, etc.
7. Inventory of major existing transportation routes, traffic estimates and bottlenecks, as well as projected transportation projects in the region.
8. Identification of existing and projected recreation facilities and open space
9. Inventory of flood prone land in the region
10. Identification of regional zoning maps, and summary of land use controls employed in the region
11. Location of lands which cannot or should not be developed, e.g., steep slopes, wetlands, critical fish and/or wildlife habitat.

It should be noted that the data categories listed above may or may not be utilized for specific regional land use planning efforts. In addition, the data may be aggregated and displayed in many different formats. Where such data are available, they should be reviewed for use in the 208 program. The land use data needs for areawide water quality management are outlined in the next subsection.

C.2.2 208 Land Use Data Needs

Despite the fact that some data compiled for traditional comprehensive land use planning efforts may be directly useful in 208 planning, there are likely to be certain deficiencies in those data when it comes to applying them in the specific context of water quality management planning. These deficiencies are attributable to the lack of emphasis given to water quality concerns in many traditional comprehensive land use programs. This lack of emphasis will result in the need to seek out other sources of information to fill data gaps in a manner that facilitates the development of alternative 208 plans, and the evaluation of those plans. Subsequent sections of this Appendix provide suggestions for the collection of such data. This subsection

identifies a range of land use-related data needs that might be considered by the 208 planner in data collection efforts.

The range of 208 specific land use data needs is summarized in the following list:

1. The size and location of each major drainage area in the planning region in square miles or acres
2. The percentage of various existing land uses in each drainage area, e.g., forest land, cropland, residential land (by density), industrial land, etc.
3. The physical land characteristics of each drainage area including soil types and soil characteristics (drainage, erodibility, etc.), slope, vegetation, and estimated gross percentage of impermeable cover (due to roofs, roads, parking lots, etc.)
4. The geology of the region as it relates to the presence of confined and unconfined aquifers, aquifer recharge areas, depth to groundwater, and known areas of groundwater contamination, e.g., salt water intrusion etc.
5. The location of critical regional environments including key fish and wildlife habitat, wetlands, shorelands, flood prone areas etc.
6. The delineation for each drainage area of water distribution and sewerage systems (including the location of water treatment and wastewater treatment facilities), and the identification of those areas served by wells and septic tanks or package treatment plants
7. The projection of trends in regional development as it might affect changes in land use configuration (and thus runoff characteristics), the need for additional water and sewer service, and the physical character of the land surface
8. The identification and location on maps of major point sources and significant nonpoint sources by drainage area, along with the location of residual waste disposal sites in the planning region

9. Identification of present and projected areas of mining activity, along with major construction sites, e.g., large subdivisions, industrial parks, dam sites etc.

Some of the above data will be extractable from existing local data sources in one form or another. The format and/or the level of aggregation of the data will often require standardization on drainage area maps to optimize the utility of the information for the 208 planner.

C.2.5 Notable Similarities and Differences Between Data Needs for Traditional Land Use Planning Efforts and Those of the 208 Program

Data required for traditional land use planning programs commonly will provide the basic context for the land use element of 208. Portions of the existing land use data base will be applicable to the data needs of the 208 program, and maximum use should be made of existing data and previous land use analyses. This subsection is designed to compare and contrast the data needs of these two kinds of land use planning programs. The intent is to provide the 208 practitioner with some assistance in identifying potentially useful data that may be found in local data bases, as well as in pinpointing where additional data collection efforts may be necessary. The discussion that follows must necessarily be general in nature, since the available land use data bases at the regional level may vary considerably from one designated area to another. Table C-1 summarizes the comparative analysis of land use data needs, and may be consulted to supplement the discussion that follows.

The similarities between data commonly available from traditional land use planning efforts, and the needs of the 208 program are significant. For example, the physical characteristics of the land surface, as outlined previously, are often detailed in traditional land use programs. This information is also commonly displayed on regional maps to facilitate the effective utilization of the data. These maps and their supporting documentation, e.g., aerial photography and land use plan narrative, are likely to be useful inputs to the 208 planning process relative to the identification

TABLE C-1

COMPARISON OF TRADITIONAL AND 208-SPECIFIC LAND USE DATA NEEDS

Data Type	Traditional Land Use Program	208 Land Use Element
1. Physiographic data	Soils, slope, and vegetation data etc. are currently used to identify physical development constraints and critical regional environments, e.g., important wildlife habitat.	Soils, slope, vegetation, climatological, and geological data are used to estimate anticipated surface runoff characteristics and thus non-point pollution loads.
2. Demographic data	Population projections by various time increments, e.g., by 10-year intervals, are used to estimate the future need or demand for various land uses in the region, e.g., residential, commercial, etc. (Usually done by political subdivision.)	Population projections in 5-year increments for 20 years to estimate the need or demand for various land uses, as well as the demand for water and sewer services. (Best done by hydrologic unit or water/sewer service area.)
3. Additional land use data	Using population projections, and information on land use controls, e.g., zoning maps, transportation plans, etc., the future regional land use configuration is estimated within physical and institutional constraints. (Usually done by political subdivision.)	The same information is used to project one or more future land use configurations, but the projections are taken further to estimate changes in land surface characteristics and activities that would geographically affect water quality, and the demand for water and sewer services. (Best done by drainage area or hydrologic unit.)

of key land surface characteristics, such as slope and soil types, necessary to implement various water quality modeling techniques. Likewise, demographic projections are important inputs to the traditional land use planning process. EPA 208 Guidelines require the use of OBERS Series E (Office of Business and Economic Research Statistics) projections, except where more reliable demographic information is available from other sources at the state and/or regional level. In this case, the designated 208 agency should substantiate the reasoning for their variance before proceeding with the use of projections other than those of OBERS. In either case, the projections will likely be aggregated in different geographic units than would be optimal for the 208 program, e.g., population by traffic zone instead of by drainage area. This will necessitate the interpolation of the existing projections to translate the information to the appropriate unit of analysis, in this case the hydrologic unit.

There are several other similarities in data needs between these two types of land use programs that the 208 planner should be aware of. Traditional land use planning efforts usually recognize the importance of the provision of water and sewer services to regional development, and thus may have the water and sewer service areas mapped, along with projected extensions of these service areas. This information is of direct use to the 208 program. The existing land use maps generated by traditional comprehensive planning programs, and the projected future land use configuration of the planning region for some future base year, e.g., 1981 or 2000, also provide important information to the 208 planner. Here again, the existing and projected land use data will, in all likelihood, have to be reassembled by drainage area to be of use in the water quality evaluation/modeling element of 208. In addition, available land use projections may have to be interpolated to allow the 208 planner to describe changes by 5-year intervals over a 20-year planning horizon for the land use/water quality analyses. Existing zoning maps should be collected and consulted as the above interpolations are made, since those maps will be significant in shaping the future configuration in the urbanizing areas of the region. Any major transportation projects that are likely to significantly modify regional drainage patterns should also be identified from existing comprehensive plans or transportation

plans. This information will be of importance to the 208 planner from both a land use and water quality standpoint.

The differences between the data needs of traditional land use planning programs and the needs of the 208 programs may be attributed primarily to a difference in program focus. The 208 program concentrates on developing solutions to water quality problems in a comprehensive fashion dealing with both point and nonpoint sources, as well as with structural and nonstructural control techniques. In contrast, traditional comprehensive planning efforts address water quality considerations in a relatively superficial fashion in most cases. This explains why the land use element of 208 has some data needs that are not likely to be met from data collected in traditional land use planning programs. This also helps explain why the data needs of 208 may require a reaggregation or manipulation of the data available from traditional land use planning programs.

C.3 Identification of Existing Data Sources and Characteristics

Due to the significant constraints of time and budget, 208 planning agencies should utilize existing land use data sources within the 208 region in order to avoid the unnecessary expenditure of resources in land use collection efforts which duplicate already existing data. Identifying, locating, and obtaining existing land use data from primary and secondary sources is the initial basic step in a land use planning effort.

A significant amount of land use information is often required in order to understand and document past development trends, current status, and possible future directions of land use patterns within the 208 region, especially as all this relates to water quality. Although numerous land use data sources normally exist for any region, the information is often scattered throughout the files, libraries, and information systems of many Federal, state, and local public agencies, and even some private sources. Often the land use information from such sources is in a format which is not directly useable by 208 agencies. The 208 program like other emergent Federal and state programs (see below) related to land use, has created demands for

specific types of land use information related to air and water quality, and environmental protection not previously collected or routinely available to public agencies.

This section of Appendix C provides a general listing of the types of land use data applicable to 208 planning that are normally available from various Federal, state, regional, and local sources. The objective is to provide the 208 planner with some assistance in locating appropriate land use data sources.

C.3.1 Federal Data Sources

Although many Federal programs (such as those under the Coastal Zone Management Act, the Clean Air Act, the Federal Water Pollution Control Act, and the Flood Insurance Act) have substantial primary and/or secondary impacts on the use of public and private land, no comprehensive catalog or directory of Federal land use data sources exists. While such a compilation has been proposed, efforts to date have stopped short of listing data series items in a "shopping list" format preferred by planners. However, several Federal departments have compiled directories of data and information systems within their agencies. Unfortunately, knowledge of how land is currently being used across the United States is incomplete for major portions of the country. Nonetheless, the paragraphs that follow outline the principal Federal agency repositories of land use data of potential value to the 208 plan; and a foldout matrix of Selected Federal Programs Related to Regional Planning is attached at the end of this Appendix.

Six Federal agencies are likely sources of relative land use materials relevant to 208 land use planning. These agencies are as follows:

1. U.S. Department of Agriculture (USDA)
2. U.S. Department of Commerce (DOC)
3. U.S. Department of Housing and Urban Development (HUD)
4. U.S. Department of Interior (DOI)
5. U.S. Army Corps of Engineers (CoE)
6. U.S. Environmental Protection Agency (EPA).

land use information from these agencies commonly exists in descriptive, inventory, statistical, and/or map formats, and is often available or obtainable through local or regional offices of these agencies. Agency headquarters addresses and telephone numbers are provided in Table C-2 for each of these agencies. Reference to local offices may be subsequently obtained from the respective headquarters operations.

The U.S. Department of Agriculture sponsors several continuing programs which provide data on the acreage and condition of the nation's total natural resources base.[2] The National Cooperative Soil Survey program of the Soil Conservation Service (SCS) has completed detailed maps of soil classifications and interpretations at scales of 1:15,840 to 1:24,000 for about 55 percent of the total U.S. land area. Reconnaissance soil maps at 1:250,000 and smaller scales are available for most parts of the country. Information contained in the detailed county soil survey reports can be used to appraise the effects of alternative land uses on the environment, and on the net productivity of the land resource; and to evaluate soil hazards and suitability for:

1. Farm and rural uses such as selection of kinds and varieties of crops, management practices, and yield predictions
2. Non-farm uses including location, design, and expected performance of local roads, streets, low buildings, septic tanks, sanitary landfills, and reservoirs
3. Forestry, recreation, and wildlife uses
4. Location of mineral deposits etc., e.g. gravel, sand, topsoil, and roadfill, and
5. Miscellaneous uses such as shopping centers, housing subdivisions, and industrial parks.

Watershed surveys, e.g., the P.L. 566 Small Watershed Program of the SCS, and cooperative river basin studies, commonly include map and tabular data of current and projected land uses (up to 50 years in the future) for such land use categories as cropland, pasture, forest, urban, and others.[3] Specialized areas such as flood plains and wetlands are also usually identified in such studies. This type of information can provide important input to the evaluation of alternative land use configurations for meeting present

TABLE C-2
[illegible]

Federal Agency	Headquarters Address	Telephone Number	Land Use Information Available
U.S. Department of Agriculture	14th St. and Independence Ave., S.W. Washington, D.C. 20250		
Office of Communication	(name)	(202) [illegible]	Information Sources
Rural Development Service	(name)	[illegible]	Rural Data
Agricultural Stabilization and Conservation Service (ASCS)	(name)	[illegible]	Conservation Programs
Extension Service	(name)	[illegible]	Extension Programs
Forest Service	(name)	[illegible]	Forestry Programs
Soil Conservation Service	(name)	[illegible]	Soils Data and Maps
Economic Research Service	(name)	[illegible]	Agricultural Production
U.S. Department of Commerce			
National Oceanic and Atmospheric Administration Office of Coastal Zone Management	[illegible] Executive Boulevard Rockville, Maryland 20852	(301) [illegible]	Coastal Zone Management Programs
Social and Economic Statistics Administration	Bureau of the Census Washington, D.C. 20234	(301) [illegible]	Population/Economic Data
U.S. Department of Housing and Urban Development	451 Seventh Street, S.W. Washington, D.C. 20410	(202) [illegible]	701 and Block Grant Programs & Flood Plain Programs
U.S. Department of the Interior			
National Park Service	Washington, D.C. 20240	(202) [illegible]	Parks and Recreation
Bureau of Land Management	(name)	[illegible]	Public Land Management
Bureau of Outdoor Recreation	(name)	[illegible]	Recreation
Bureau of Reclamation	(name)	[illegible]	Western Water Resource Development
Bureau of Mines	2401 E Street, N.W. Washington, D.C. 20241	(202) [illegible]	Resource Inventories
Geological Survey	12201 Sunrise Valley Drive Reston, Virginia 22092	(202) [illegible]	Land Use & Resource Maps & Information, Aerial Photography
Bureau of Indian Affairs	1951 Constitution Avenue, N.W. Washington, D.C. 20240	(202) [illegible]	Indian Reservation Information
U.S. Army Corps of Engineers Office	Chief of Engineers Department of the Army Washington, D.C. 20314	(202) [illegible]	Public Works, Designing & Flood Plain Management Information
U.S. Environmental Protection Agency		(202) [illegible]	EPA Land Use Policy
Office of Land Use Coordination	401 M Street, S.W. Washington, D.C. 20460		
Water Planning Division	(name)	(202) [illegible]	EPA 208 Program Activities

and projected land use needs in the 208 program.

The Census of Agriculture and Forest Service Statistical Reporting Service programs provide annual statistical tabulations of land areas in crops, forest, and other agricultural uses on a county basis for most of the U.S.[2] The USDA Soil and Water Conservation Needs Inventory provides a land use inventory of over 19,000 watersheds and indicates those watersheds that are potentially feasible for development under the Watershed Protection and Flood Prevention Act (P.L. 566). County totals of data collected during this inventory are published for each state in tabular format according to a seven-category land capability classification scheme which relates to the capability or suitability of the landscape for agricultural purposes. This information is commonly available at state SCS offices. Aerial photography at scales of 1:24,000 and smaller is used in several USDA agricultural programs. This photography is available for nearly every county in the United States and may include several years of photography that documents historical land use change in the region. Information about available USDA photography may be obtained from county SCS and/or ASCS offices. The photography may be purchased in print and index sheet formats from the USDA Data Center at the following address:

U.S. Department of Agriculture
2505 Parley's Way
Salt Lake City, Utah 84109
(801) 524-5856.

The U.S. Department of Interior, whose responsibilities include the management of over 500 million acres of Federal land, has several programs which generate land use data. The National Cartographic Information Center (NCIC) has been established to provide users with one-stop access for acquiring information about maps, charts, geodetic control, aerial and space imagery, and related cartographic data generated by Federal and ultimately state, local, and private sources. The NCIC usually does not hold the data for which it provides information and access, but it manages a system that provides a link between the user and the data. The center enables customers to find out what cartographic information and materials are available, to

place an order, to pay or submit a purchase order, and to receive copies of the information or materials in a reasonable time. The NCIC is both an active information office and the management center of a network of linked data repositories, including those not administratively part of NCIC.[3] The address of the National Cartographic Information Center is:

U.S. Geological Survey, Stop #507
National Center
Reston, Virginia 22092.

The Resource and Land Investigations (RALI) program of the Land Information Analysis Office (LIA) within USGS, and the Divisions of Topography and Geology provide several maps and related land use data bases applicable to 208 planning. Through the Land Use Data and Analysis (LUDA) program begun in 1974, the USGS is undertaking the first comprehensive land use inventory of the United States using the same land use classification system.[4] High altitude National Aeronautics and Space Administration (NASA) photography and other supplementary data are being analyzed with a sophisticated machine-aided analysis system to perform this inventory. The land use classification system is comprised of seven generalized Level I land use categories which are subsequently broken down into more detailed land use classifications. The seven Level I categories are:

1. Urban and Built-up Land
2. Agricultural Land
3. Rangeland
4. Forest Land
5. Water
6. Wetland
7. Barren Land.

The LUDA program was expected to provide 1:250,000 land use and land cover maps for the entire U.S. by 1980. However, this target date may not be reached because of funding problems. The minimum areal unit to be mapped is 10 acres for urban and built-up uses, water areas, confined feeding operations, other agricultural land, and strip mines, quarries, and gravel pits. All other land use/land cover categories, including Federal land holdings, are being delineated with a minimum unit of 40 acres. For each land use and

land cover map being produced, overlays also are being compiled which show Federal land ownership, hydrologic units, counties, and political subdivisions. Computerized graphic displays and statistical data on current land use and land cover will also become available through the program. However, LUDA land use information and products for specific 208 regions may not be completed in time to be useful to 208 programs and the level of detail may not be sufficient to fill specified land use data needs. To determine the status of the LUDA program for a specific region contact:

Dr. James R. Anderson
Chief Geographer
U.S. Geological Survey
12201 Sunrise Valley Drive
Reston, Virginia 22092
(703) 860-6344.

The National Topographic Map Series of the U.S. is complete only at 1:250,000 but topographic maps are most commonly used by local and regional organizations at a scale of 1:24,000 and 1:62,500 for mapping of land use, geological and topographic features, and many other purposes since such maps include relief (by contour lines), water bodies, vegetation, and cultural features. Orthophotoquad maps, which are vertical aerial photographs in quadrangle format and which combine the metric qualities of a line and symbol map with the visual qualities of a photograph, and other planimetric base maps are being prepared by USGS in a 5-year program to provide, by 1977, 1:24,000 base maps for all areas not currently covered at that scale. Also, the National Topographic Map Series is the only nationally available base map series tied to the geodetic control network, and therefore the only one that can provide the positional accuracy needed for computer data handling. An extremely handy reference available from NCIC is a pamphlet entitled, "Types of Maps Published by Government Agencies". The pamphlet gives a listing of types of maps, their publishers, and addresses where more information may be obtained about ordering procedures. Topographic maps are also available from state Geological Surveys.

Geological and mineral resource maps are generally available at small scale

(mostly 1:250,000) from the Geological Survey. The Bureau of Mines also collects, compiles, analyzes, and publishes statistical and economic information on all phases of mineral resource development, including the exploration, extraction, processing, and use of mineral resources, and the reclamation of lands disturbed by mineral extraction and processing. Other agencies within the Department of Interior such as the Bureau of Land Management (BLM), Bureau of Outdoor Recreation, Bureau of Reclamation, National Park Service, and the Bureau of Indian Affairs may also have selected land use information on specific areas under their jurisdiction which may be located within or adjacent to the boundaries of a 208 region. BLM and EPA have established a cooperative agreement to share data and planning efforts in regions where BLM administered lands are significantly involved in the 208 program.

The Department of Housing and Urban Development (HUD) maintains some regional land use data, *e.g.*, maps of flood hazard areas. However, the focus of HUD's land use activities is on providing block grants to assist state and local governments in dealing with community development planning efforts. HUD also administers the 701 comprehensive planning program whose regulations now require that each recipient state formulate a land use policy by August, 1977. The land use outputs of the 701 program at the state and regional level will include:[5]

1. Long- and short-term policies, and where appropriate, administrative procedures and legislative proposals, with regard to where growth should and should not take place
2. The type, intensity, and timing of growth
3. Studies, criteria, standards, and implementing procedures necessary for effectively guiding and controlling major decisions as to where growth shall and shall not take place
4. Policies, procedures, and mechanisms necessary for coordinating local, areawide, and state land use policies with functional planning systems (e.g., coastal zone management, air and water quality, transportation, solid

waste etc.) and with capital investment strategies, when available, and improvements in governmental structures, systems and procedures that will facilitate the achievement of land use objectives

5. Consistent land use and housing policies.

The availability of specific land use information, e.g., from 701 programs, can be acquired from regional planning agencies (often the 208 agency also), and from HUD district offices.

An interagency agreement between HUD and EPA has also been established to insure consistency between the 701 land use element and the land use-related provisions of the water quality management plan. The agreement also states that performance criteria will include the land use outputs for both programs.

Within the Department of Commerce, the Bureau of the Census serves as a center for collecting, compiling, analyzing, and publishing a broad range of general purpose statistics dealing with economic, social, and demographic data which may be indicative of land use characteristics in a 208 area. However, rather than being based on standard map series or linked to precise geographically referenced points, the socioeconomic data series is referenced to street addresses, city blocks, or census tracts, or they are aggregated to even larger units such as minor level divisions, cities, urbanized areas, counties, SMSA's, states, or water resource regions. The water resource regions approximate hydrologic units in that they are defined by county within major river basins. It should be noted that data disaggregation will likely be necessary since the designated 208 region will seldom coincide directly with the units used to aggregate land use information for other purposes. Many of these units are also shifting spatial areas in the sense that their boundaries are subject to changes over time which may require interpolation of the data for trend analysis studies. Census data are generally available in published tabular formats at local public libraries. The National Oceanic and Atmospheric Administration (NOAA) also located within the Department of Commerce administers the Coastal Zone Management Program in which 30 participating states are required to prepare land use

plans as part of their coastal zone programs. However, NOAA itself is not a source of land use data. The 208 planner should make full use of any land use information available from a Coastal Zone Management agency whose program includes all or part of the 208 study area.

The U.S. Army Corps of Engineers may have specific map and statistical land use information available from the river basin inventories and flood plain studies they commonly undertake. Urban Study and Environmental Reconnaissance Inventory Programs that are currently under way at some of the Corps Districts may generate land use data useful in 208 planning efforts.

The U.S. Environmental Protection Agency maintains a small Office of Land Use Coordination but does not collect or disseminate land use data. However, EPA does maintain computer files of air quality (SAROAD) and water quality (STORET) data which may be of primary value in 208 land use planning programs. EPA also has a Remote Sensing Laboratory in Las Vegas, Nevada, and an Environmental Photographic Interpretation Center (EPIC) in Warrenton, Virginia. In addition, EPA has sponsored considerable land use research of direct relevance to the 208 program. The reports from some of these studies are cited in the annotated bibliography section of Appendix D.

C.3.2 State Data Sources

The availability of state land use data varies considerably from state to state. Few states have undertaken a general indexing of land use data sources, and only nine states have adopted a major state land use program: Colorado, Florida, Hawaii, Maryland, Nevada, North Carolina, Oregon, Vermont, and Wyoming. Less than half of the 50 states have land use maps covering the state at any scale, and less than a dozen have detailed information. The maps that do exist range widely in scale, resolution, classification categories, sources, age, and purpose. Most state maps are overlays of the National Topographic Map Service at scales of 1:500,000 or 1:250,000, which consequently may not provide detailed information required for 208 land use planning programs. Usually, the most current land use information available at the state level has been assembled as part of a specific Federal program

such as the HUD 701 Comprehensive Planning Program or the NOAA Coastal Zone Management Program. The major type of state agencies from which land use data can most likely be obtained include the departments/agencies of Agriculture, Natural Resources, Development, Transportation, Geological Survey, and Aerial Engineering.

C.3.3 Regional/Local Data Sources

Probably the land use information most relevant (in terms of useful format and availability) to 208 programs is likely to be available from regional/local sources. As previously mentioned, certain federal and state offices located in the general area are likely to be good sources of state or federal land use information for that region. In addition to maintaining local historical information, public libraries are also repositories for many state and federal documents. Libraries may also have copies of general environmental information, and environmental impact statements which may contain pertinent land use information. Land ownership records (if required) are commonly available at the office of the county recorder. Regional planning agencies (which may be the designated 208 agency) maintain libraries of published and unpublished land use data and maps, as well as topographic base maps, that have been compiled during HUD 701 or EPA 201 planning programs. These agencies also are normally responsible for preparing growth projections and maintaining land use control maps such as zoning maps. County and/or city public service departments and special district organizations, e.g., sanitary districts or drainage districts, maintain transportation base maps, water and sewer service maps, and park and recreation maps. Private utility companies (electricity, gas, and telephone) also normally maintain utility corridor maps and frequently conduct land use inventories and prepare land use projections for business planning purposes. Local Chambers of Commerce may also have relevant land use information, and sometimes compile demographic data for the half interval between national census dates.

C.4 Matching Land Use Data Needs with Available Data Sources

Now that potential land use data needs have been identified and compared with the data needs of more traditional land use planning programs, and

the federal, state, and local data sources have been characterized, this section will briefly discuss the matching of the perceived data needs with the available data sources.

Since data availability is likely to be one of the most significant constraints in selecting techniques for the land use and the water quality analyses, it is often best to do a preliminary data collection survey in order to identify any major data gaps that could preclude the use of certain techniques. This preliminary survey of data availability from federal, state, the local sources should help give the 208 planner a reasonable indication of the quality of the existing land use data base for the study area. When this information is compared with the data requirements of the various land use analysis techniques available for use, deficiencies in the data base will emerge as well as the presence of extraneous data that are not necessary to accomplish subsequent land use and water quality analyses. The data gaps identified will require the development of plans for primary and/or additional secondary data collection efforts. These plans should include estimates of the costs anticipated for additional data collection, since the constraints of budget may necessitate the use of a less sophisticated land use analysis technique, more fitted to the existing data base, where the costs of acquiring the data necessary to employ a more sophisticated technique are prohibitive.

The objectives of the preliminary data survey may be summarized as follows:

1. To assure that the data requirements of the selected land use and water quality analysis techniques are met by the existing land use data base, or can be met with additional secondary, and if necessary, primary data collection efforts, e.g., new aerial photography, at reasonable cost
2. To eliminate early in the evaluation process those data that are extraneous to the specific needs of subsequent analyses.

Meeting the above objectives will help minimize the time and money spent on

subsequent data collection and analysis.

Thus, the selection of land use data management and analysis techniques consistent with the results of a preliminary survey of data availability is a very important step in the land use element of the 208 planning process. If relatively simple, manual land use evaluation techniques will be employed, the data needs will not be as demanding, and the data sources will likely be more easily accessible. The more demanding the data requirements of the selected technique, the more rigorous the search of data sources is likely to have to be in order to meet those requirements.

With respect to filling identified data gaps a more thorough search of data from the same kinds of data sources previously identified is a logical first step. Where additional secondary data cannot be found to fill data gaps, primary data collection efforts may be required. Such efforts might include having the planning area flown to acquire current aerial photography supplemented by selected field surveys, for example.

Section C.7 discusses the data input requirements and product outputs of a range of land use and demographic analysis techniques in more detail. This section should be of some assistance to the 208 planner in matching the data requirements of desired techniques with the quality of the existing land use data base as identified in a preliminary survey of data sources.

The next three sections provide more detailed information on the subjects of land use data collection, data management, and data analysis, respectively. Each section discusses the range of potentially applicable approaches to each topic, from simple to complex.

C.5 Land Use Data Collection Techniques

The land use element of the 208 program must initially describe the existing land uses within the designated study area. The 208 agency can complete this requirement in two ways:

1. Existing secondary land use data commonly available within

the 208 agency and from other relevant sources can be utilized with little to no primary data collection efforts, or

2. Inventory programs can be established for the collection of primary land use data.

Factors which should be considered before initiating a land use data survey include:[6]

1. Costs
2. Availability of trained professional personnel
3. Constraints of the time frame imposed
4. Utility of the data in subsequent analyses
5. Reliability of the data in terms of quality
6. Ease of data base updating
7. Versatility in displaying and extracting information from the data useful in other agency programs.

EPA 208 Planning Guidelines state that the process of incorporating land use considerations into the 208 plan should rely primarily on utilizing existing land use plans, projections, and controls. However, in some 208 regions, the necessary land use information available from secondary data sources is inadequate to support the desired level of analysis. Existing regional land use statistics and maps available from secondary sources are often prepared for other purposes. Thus, they may not provide comprehensive coverage of the designated 208 region. Land use map and statistical information acquired from various secondary sources generally vary in format. The age and accuracy of data may also vary.

In general, when any new source and/or method of data acquisition is being considered, it is necessary to assess whether it is more efficient (cost-effective in terms of time, money, and manpower) to collect new data directly or to collect, collate, and possibly reorganize or reformat existing data bases and fill existing data gaps. Governmental programs and/or funds for collecting specific land use data required for a 208 plan generally are limited. Care must be exercised so that the land use data collection

activities do not become an enormous "sink" for both manpower and funds, which can easily occur, particularly if the ultimate use of the land use information is not kept in view at all times.

In the following sections, a range of simple to sophisticated alternative land use data collection techniques is described to aid the JHM planner in the collection of new data and in the filling of identified data gaps.

C.5.1 Relatively Simple, Low-Cost Land Use Data Collection Techniques

This subsection will describe some land use data collection techniques that are relatively elementary in design and that do not require expensive or sophisticated equipment, extended allotments of time, and significant formal prior training, but result in reliable land use information for filling land use data requirements. The four specific techniques presented below include extraction of land use information from:

1. Census data and Water Resources Council OBERS (Office of Business and Economic Research Statistics) regional economic activity projections in the United States
2. Existing land use projections and supporting documents such as zoning maps and water/sewer service area maps
3. Aerial photography.

More sophisticated and expensive land use information collection techniques are discussed in subsection C.5.2.

C.5.1.1 Census and OBERS Data

Bureau of the Census data include several series of publications, data files, and special tabulations. Unpublished nonstatistical materials such as maps and computer programs can be made available from the Bureau of the Census (subject to restrictions on disclosure of confidential information), for the cost of reproducing, transcribing, or tabulating the material. Census data generally available in local libraries may include the general statistical compendia and special publications covering the subjects of Agriculture, Construction and Housing, Foreign Trade, Geography, Government, Manufacturing

and Mineral Industries, Population, Retail Trade, Wholesale Trade, and Selected Service Industries, and Transportation. The Census Bureau's County and City Data Book is also a good summary source of census information by county. Additional information is available from the Bureau of the Census (including a description of surveys and computer products), and can be found in two publications:

1. Bureau of the Census Catalog, and
2. Bureau of the Census Guide to Programs and Publications.

The catalog is issued quarterly, while the guide reviews Bureau of the Census programs and publications in the 1960's and 1970's. If these two documents are not already in the library of the designated 208 agency, they are commonly available at public and university libraries, or they can be ordered from the U.S. Government Printing Office, Washington, D.C., 20402. The most important publication from the Bureau of the Census relative to population projections is entitled Population Estimates and Projections. This series of documents is published annually, and includes population estimates by county and by Standard Metropolitan Statistical Area (SMSA). These population estimates are also disaggregated to the township level for the census year, e.g., 1970, and a more current year, e.g., 1973.

OBERS projections are a planning tool prepared in response to a need for basic demographic and economic information by public agencies engaged in comprehensive planning for the use, management, and development of the nation's water and related resources. Various series of the projections have been published which correspond to the series of projected United States population estimates published by the Bureau of Census. OBERS reports include projections of economic activity for the nation; the 173 functional economic areas delineated by the Bureau of Economic Analysis for economic analysis; the 20 water resources regions and the 205 subareas, delineated by the Water Resources Council; the 50 states and the District of Columbia; 253 Standard Metropolitan Statistical Areas (SMSA's); the 173 non-SMSA portions of economic areas; and, the 204 non-SMSA portions of water subareas. Included are projections of population, personal income, employment, and earnings of persons, by industry for various years from 1980 to 2020. Also included are projections of land use by broad categories for the

same 50-year period but with fewer intervening years covered. However, the amount of detail included in the OBERS projections varies by type of area, primarily because of the differences in the availability of historical data. The latest Series E OBERS Projections, and those which the EPA 208 Guidelines require for use, are based upon the Series E projected national population (1972). The data are available in seven volumes outlined as follows:

1. Volume I. Concepts, Methodology, and Summary Data
2. Volume II. BEA Economic Areas
3. Volume III. Water Resources Regions and Subareas
4. Volume IV. States
5. Volume V. Standard Metropolitan Statistical Areas
6. Volume VI. Non-SMSA Portions of BEA Economic Areas, and
7. Volume VII. Non-SMSA Portions of Water Resources Subareas.

Census and OBERS data must first be aggregated as accurately as possible for the designated boundaries of the 208 region. If appropriate, the OBERS data can be utilized for baseline and future population projections within the 208 study area. However, care must be exercised in using the OBERS projections, or any projections, in that the assumptions postulated and methods used to derive the projections must be consistent with the anticipated use of the data. Nevertheless, such projections provide an approximate indication of future conditions and may be further used as a benchmark framework for evaluation purposes.

If the existing land use and demographic baseline data and/or projections cannot be utilized or are not available, then available historical data may be used to provide a reasonably accurate indication of future population growth. Several approaches may be employed to produce such projections. However, there is no method which will yield results with 100 percent accuracy. Simple mathematical extrapolations of historical data based on some linear or curvilinear function are the easiest methods to apply. More complex methods include separate analysis of the individual socio-economic components (such as economic base activity) that impact population change, under various assumptions.

In general, population projections are based on techniques which analyze changes in birth, death, and migration components of population change. The three demographic methodologies most frequently used are the component, cohort-survival, and ratio methods.[7] Each of the three methods commonly utilize census data. The component method uses total population data to derive separate projections for births, deaths, and net migration. Those projected components can then be summed algebraically and added to the existing base population to derive the projected population at a future date. The cohort-survival method is the same as the component method except age-specific detail is used to derive all of the component projections. The ratio method is a projection of local area population based on the ratio of the local area population to the population of some larger area for which accepted projections are available.

C.5.1.2 Existing Land Use Data

As discussed in Section C.5., the most comprehensive sources of relevant land use information available to the 208 agency will probably be city/county and regional planning agencies located within the designated 208 region. Additionally, state and Federal offices located within the region may be sources of relevant information. All of the data available at these agencies may not be published, and original data from surveys may exist. Where this is the case, the data might be loaned to the 208 agency for analysis.

Planning documents and maps generally depict existing land use conditions and project future land use based on a set of development assumptions. A community planning document generally contains the following five elements:

1. A historical perspective of regional development
2. Inventories of existing environmental, population, land use, housing and transportation, and social conditions in the community
3. A discussion of the major development issues and community development goals
4. A projection of future conditions within the community and region, and

5. Recommended implementation policies, standards, and controls. Such documents should be carefully reviewed to extract relevant water quality/land use information.

Cursory examination of other various secondary data sources may identify interrelationships among the factors that affect land use within the region. For example, it may be determined from census data that the population of a city has increased by an average of 150,000 residents per decade since 1940. From tax assessment records it might be established that acres of residential land use have increased an average of 50,000 acres per decade over the same time period. Therefore, if a relatively stable relationship between population growth and residential land use expansion exists, the future increase in residential acreage may be estimated. This, of course, assumes that the historical trend will continue into the future.

Various large scale map and supporting statistical data available from sources within the 208 region generally will contain information useful for updating existing land use information and for estimating future land use patterns. Generalized slope maps can be derived from existing topographic maps by measuring the linear distance between contour intervals and determining the ratio of the linear distance to the distance between contour intervals. Street maps, subdivision plat maps, and records of building permits are frequently used to update existing land use map and statistical information. Zoning maps and other land use control documents, and existing and proposed public water and sewer lines can serve as guides in projecting the location of future growth. Sanborn maps, which are prepared by fire insurance underwriters, also provide very detailed land use information for updating maps. Features included on these maps include streets, railroad tracks, building dimensions, and uses of buildings in commercial areas of cities. If available for a given region, these Sanborn maps can be obtained from major insurance companies operating in the study area.

The above land use data collection techniques utilizing existing land use materials are best suited for urbanized areas of the region. Land use information for nonurbanized areas is generally not as abundant. This information

generally relates to resource utilization and production rather than to land development. Probably the best sources of land use information for rural areas are compilations of township tax maps and data. Depending upon the jurisdiction, breakdowns of agriculture land use acreages may be provided for various tax rates by lands in cultivation, pasture, forest, built-up areas, and water bodies. Tax records also commonly indicate acreages of commercial, residential, and industrial land on a parcel-by-parcel basis. Location and production volumes of extractive industries are potentially available from state or county offices which issue permits for resource extraction. Agricultural production statistics and soil maps of the area are usually obtainable from the local county office of the Soil Conservation Service (SCS), the local cooperative extension service agent, and other agricultural organizations. Rural zoning legislation (if existing) may also provide an indication of future land use and water quality conditions within the rural area. Regional offices of the U.S. Forest Service may also have useful data on the renewable resources and land use patterns of a given region.

C.5.1.3 Aerial Photographic Data

Conventional aerial photography (panchromatic, color, and color infrared imagery) from low to medium altitudes (5,000 to 30,000 feet) is generally available or readily obtainable at relatively large scales in print or transparency format from local aerial survey companies. Aerial photographs acquired at these altitudes possess sufficient resolution from which a considerable amount of data on existing land use and natural resources can be extracted. The expense of acquiring new aerial photography may not be economically justifiable if the intended use of the data is for supplemental 208 land use information, unless the photography can be acquired as part of another governmental program and/or can be flown by a governmental agency.

A photographic scale of 1:24,000 (1" = 2,000 ft.) is very appropriate for 208 planning purposes since USGS topographic maps and other reference data are often mapped at that scale or multiples thereof (1:12,000 or 1:48,000). Another optimum scale is 1:63,360 (1" = 1 mile). The 9" x 9" black-and-white prints can be duplicated for approximately $3 each.[8] Index sheets

and a controlled mosaic of aerial photography in print format at 1:24,000 can be readily used for data analysis purposes and as a communication medium for public participation purposes. These aerial photographic products should be prepared by professionals. Enlargements of high altitude National Aeronautics and Space Administration (NASA) or Department of Interior color or color infrared photography can be similarly used.

A 208 agency staff member with photo-interpretation experience, or an aerial survey company familiar with the landmarks and characteristics of the 208 region, can use a mosaic of aerial photographs, transparent overlay material, and perhaps a stereoscope or a small magnifying glass to identify, delineate, and construct map overlays of the major land use features (such as industrial complexes, water bodies, parking lots, large feed lots, and other features) of direct concern in 208 planning. Different levels of accuracy and resolution may be required for varying levels of pollutant load analysis, depending upon the criticality of a particular area. For example, it may be much more important to highlight cattle feedlots than wheat fields on maps of rural portions of the study area. If multidate photography flown a decade or earlier is available, urban/rural interfaces can be delineated; and, with a hand planimeter the urban areas measured to determine the extent, direction, and rate of urbanization.[9] The costs of obtaining a general land use classification map by purchasing and analyzing recent black and white aerial photography range from $4 to $15 per square mile.[8] While the accuracy of product will depend to a large extent upon the accuracy of the mosaic, the interpretation skills of the photo-interpreter, and the mapping techniques employed, the procedure can inexpensively satisfy certain 208 land use data requirements. However, depending on the detail of the land information required and the size of the 208 designated area, manual interpretation of aerial photographs may be impractical in terms of cost and time. Time constraints are significant because the 208 program is only a two year effort, and the land use inventory is an input required very early in the program. If time is judged to be a critical factor and the 208 agency wishes to maintain the same detail of data analysis, consultant firms possessing more sophisticated data analysis facilities may be used to provide the required analysis on a more timely basis (See Section C.5.2.).

C.5.2 Relatively Sophisticated and Expensive Techniques

This subsection will describe field survey and remote sensing techniques for collecting land use data applicable to 208 planning. Those techniques generally are more expensive and often require sophisticated equipment and specially trained personnel to provide reliable land use data compared to those techniques discussed previously in subsection C.5.1.

C.5.2.1 Field Survey Techniques

Field surveys can be made to collect land use data for a variety of reasons including to:

1. Determine the accuracy of existing land use information
2. Fill identified data gaps
3. Update and supplement existing land use data, and
4. Provide land use data for statistical field plots for extrapolation to other areas in the region via remote sensing analysis techniques.

In preparing for a field survey, existing data sources should be reviewed prior to the survey. Routes should be selected which include all areas to be visited as appropriate. Field surveys are usually accomplished by a pair of staff members traveling by auto along existing roads in the region. Two people are required as one serves as navigator and data collector while the other drives the vehicle. Visual inspection of the area can similarly be conducted by aerial reconnaissance flights flown at low altitude over the region. Such flights may provide members of the planning staff with a quick and synoptic overview of existing land use patterns of the region and is a simple way to survey remote areas that are difficult to access by other modes. Clipboards, notebooks, and existing aerial photographs and maps of the area, folded or cut to the appropriate size, on which data voids have been delineated, are required for a field survey. During the survey it may be necessary to question local residents about land uses of hard-to-access areas. Photographs of representative land uses can be taken during the field survey for subsequent inclusion in reports or for slides

for use in public presentations. Upon completion of the survey, the data should be transferred from working maps and notes into a more refined format. The costs of obtaining general land use information via windshield survey analysis are approximately $5.00/square mile.[6]

More elaborate and costly field survey methods may be required to obtain land use data on a parcel-by-parcel basis if no other sources of land use information exist. Detailed planning prior to field work is required and training sessions for participating staff are necessary to insure uniformity and to eliminate ambiguity in data classification and data collection techniques. Coding sheets with specific formats and instructions are required as well as large-scale base maps for land use data mapping purposes.[10] However, such detailed surveys will probably not be required to obtain land use data for most 208 land use planning programs. Other data collection techniques, such as interpretation of aerial photography, generally provide comparable levels of land use information quicker and less expensively.

C.5.2.2 Remote Sensing Techniques

Remote sensing (which includes satellite imagery and aerial photography) is an outgrowth of aerial photographic interpretation and involves the collection of data by systems which are not in direct contact with the objects or phenomena under investigation. The technological development of remote sensing systems (sensors and platforms) has generally outstripped corresponding development of interpretation methodologies and techniques, which are needed to convert remotely sensed data into usable information. However, interpretative and analytical procedures have been developed and demonstrated which 208 agencies can purchase from private firms to acquire land use information.

The major advantage that sophisticated remote sensing land use data acquisition and machine-aided or computerized analysis techniques provide is a timely and comprehensive analysis of the entire designated 208 area using the same data base and data evaluation scheme. Requirements for field surveys may also be reduced.

Other advantages of remote sensing techniques include:

1. Land use changes can be monitored and the corresponding map and statistical information updated
2. Interpretation subjectivity of land use classifications is minimized once spectral signatures for land use features have been determined
3. Land use features are displayed during analysis in final or near final form and require little or no additional interpretation
4. Land use features can be displayed individually and at a variety of scales
5. Statistical summary tables of land use features for any area in the region can be quickly generated.

Three major limitations of the current state-of-the-art land use applications of remote sensing techniques are:

1. The acquisition and interpretation of the data requires professional expertise and sophisticated equipment considerably beyond that existing within a typical 208 agency
2. Extensive ground truth measurements and field verification efforts may be required to assure that accuracies of 90 to 95% are achieved for detailed classifications at large scales, and
3. The cost of using remote sensing data acquisition and analysis techniques will generally exceed the cost of extracting land use data from existing data sources, unless it is more efficient to use the new data source than to perform manipulations required to put existing data into useful form.[8]

Table C-3 illustrates the various sources of remote sensing data and general applications of data obtained from the various platforms. Aircraft photography will generally be most appropriate for providing land use data required for 208 planning purposes. Table C-4 provides an indication of the film types, season and scale of aerial photography most appropriate for specific

TABLE C-1

ELEMENTS OF A COORDINATED REMOTE-SENSOR PROGRAM
FOR LAND AND RESOURCE MANAGEMENT

Data Source	Data Output Quality	Applications
LANDSAT Satellite (unmanned)	Low spatial resolution Broadband spectral resolution Small-scale wide-area coverage	Repetitive data base Synoptic update of temporal dynamic changes in Skylab derived regional land use & resource baseline Trend projection
Skylab Satellite (manned)	Moderate to high spatial resolution Narrowband spectral resolution Small-scale wide-area coverage	Static data base Land use baseline Regional land resource evaluation data base Enhance LANDSAT interpretation in defining high-priority areas
High Altitude Aircraft Photography	High spatial resolution Moderate scale	Specific coverage, as required Detailed analysis of high-priority areas Correlative data base for field activities & decision making
Low Altitude Aircraft Photography	Very high spatial resolution Large scale	Specific "pinpoint" area coverage, as required Specific land use & urban area studies Detailed engineering analyses Complete remote-sensor data base
Field Investigations	Specific point investigations Quantitative spectral measurements	Surface or urban sampling Verification of remote-sensor analyses derived from satellite & aircraft data Coordinated data base for decision-making

Source: National Aeronautics and Space Administration, Skylab Earth Resources Data Catalog, Lyndon B. Johnson Space Center, Houston, Texas, 1974, page 52.

TABLE C-4

GUIDELINES FOR AERIAL SURVEYS

Description of Task	Film Type	Season	Scale
Forest mapping: conifers	B & W Pan	Fall, Winter	1:12,000-1:20,000
Forest mapping: mixed stands	Color IR	Late spring, fall	1:10,000-1:12,000
Timber volume estimates	Pan or IR	Spring, fall	1:5,000-1:20,000
Locating property boundaries	B & W Pan	Late fall, winter	1:10,000-1:35,000
Invasive areas	B & W Pan	Late fall, winter	All scales
Topographic mapping; highway surveys	B & W Pan	Late fall, winter	1:5,000-1:10,000
Urban planning	B & W Pan	Late fall, winter	1:4,800-1:9,600
Automobile traffic studies	B & W Pan	All seasons	1:2,400-1:4,200
Surveys of wetlands or tidal regions	B & W IR	All seasons-low tide	1:5,000-1:30,000
Archeological explorations	B & W IR	Fall, winter	1:2,400-1:20,000
Identifying tree species	Color	Spring, summer	1:600-1:4,800
Assessing insect damages	Color IR	Spring, summer	1:600-1:5,000
Assessing plant diseases	Color IR	Spring, summer	1:1,200-1:7,200
Water resources and pollution	Multispectral	All seasons	1:4,800-1:8,000
Agricultural soil surveys	Color	Spring or fall, after plowing	1:4,800-1:8,000
Tagging swamp vegetation	Color	Summer	1:600-1:2,400
Real estate assessment	Color negative	Late fall, winter	1:4,800-1:12,000
Industrial municipal inventories	Color negative	All seasons	1:1,200-1:4,800
Recreational surveys	Color negative	Late fall, winter	1:5,000-1:12,000

Source: T. Lynne Every, Photointerpretation for Land Managers, Eastman Kodak Company, Rochester, New York, 1970, page 19.

data analysis tasks. In general, panchromatic black-and-white film with various filter combinations is likely to provide the most useful and inexpensive photographic data base for land use analysis. Color infrared photography is also a very useful data source for determining land use patterns but costs approximately three to five times more than black-and-white photography. Other remote sensing media, such as thermal infrared, radar and laser sensors, will probably not provide land use data that otherwise cannot be obtained by less expensive remote sensing systems. However, thermal infrared data may be very important for determining the location of point sources of thermal pollution. Assistance in the planning of an aerial survey should be sought from local aerial firms, state agencies or remote sensing schools at state universities who, from local experience, can aid in the determination of the optimal photographic film/filter and scale for a land use inventory of a particular region.

Commercial contractors and Federal and state governmental agencies are the primary repositories of existing aerial photography and have the required multispectral camera and scanning systems for acquiring recent remotely sensed data in both photographic and digital formats. In general, commercial contractors acquire aerial photography at low and medium altitudes (5,000 to 30,000 feet), and selected governmental agencies acquire and maintain large volumes of photography taken at medium and high altitudes. Satellite imagery and photography acquired as part of NASA's LANDSAT (formerly ERTS-Earth Resources Technology Satellite) space program are also available for purchase by the general public through the:

U.S. Geological Survey
Earth Resources Observation System
Sioux Falls, South Dakota 57198
(605) 594-6511

Selected aerial survey and mapping firms, specialized architectural and engineering firms, and some research and development firms have the staff and maintain the expensive facilities and equipment for machine-aided and computerized analysis of remotely sensed data. Costs for analyzing remotely sensed data are dependent mainly upon the size of the area and the number

of classification parcels per area, and to a lesser degree on the scale of the product and the difficulty of interpretation. Costs for obtaining and analyzing satellite photography to provide generalized land use classifications for a 208 region have ranged from $.50 per square mile for general classifications to $1.50 per square mile for intensive multi-feature classifications.[6]

General characteristics of remotely sensed data which are used to identify, map, and inventory natural and cultural land use/land cover features are the shape, size, tone, location, and texture characteristics of the feature on the imagery. Each land feature absorbs, reflects and emits light in a characteristic way and thus can be identified by its "spectral signature". Various combinations of filters, films and sensors are used to record the differences in spectral reflectance. Ground truth data obtained through field work and low altitude photography of small sample areas are commonly required as identification keys for identifying specific land use/land cover features of a larger area.

A variety of land use data products of direct value to 208 planning can be obtained from remotely sensed data using sophisticated techniques. Color additive viewers employ density analysis techniques to produce thematic maps that show, for example, all cement and blacktopped paved areas (impervious surface), general intensity levels of urbanized development, areas of new construction, and areas of land under cultivation. Density analysis includes the separation of photographic images to display discrete levels of reflectivity, and such viewers generally have built in electronic planimeters which give an instantaneous readout of the land area associated with the specific land use being displayed. Computers can statistically analyze massive quantities of digitized spectral data and determine fine variations between spectral responses which can also be used to identify land use patterns. Computer classified, color-coded, composite land use maps have been produced from LANDSAT imagery which show dominant land use features at an approximate cell or "pixel" size of 1.4 acres. Since LANDSAT data is in digital format, data can be summarized by county, drainage basin or other statistical unit.[11]

Major limitations of land use information obtained by the above sophisticated remote sensing data collection and data analysis techniques are that the weather must be virtually cloud free, and that unrelated land uses may have the same spectral characteristics and thus be incorrectly identified. For example, a plowed field and a construction site may be placed in the same classification, or conversely, an agricultural field crop such as wheat may be misclassified as grassland. Also, not all desired land use classifications e.g. small feedlots may be discernible at reasonable expense, and thus manual photo-interpretation or field surveys may be required to obtain certain land use classifications. In general, the more sophisticated remote sensing techniques are more applicable for obtaining land use information of large rural areas than urban areas. Land use information obtained through remote sensing programs requires field verification to determine levels of accuracy. Nevertheless, remote sensing techniques can be successfully employed to map and inventory large areas at relatively large scales on a timely basis, and produce specific land use data related to water quality programs that may not be otherwise obtainable.

C.6 Identification of Land Use and Demographic Data Management Techniques

Once land use and demographic data have been acquired from secondary sources or produced by the 208 agency, the agency must determine the procedures to be employed for managing the data. This data management function often includes data transfer, data storage, and data manipulation and extraction activities. The two basic data handling options are manual, and computer-aided techniques. Each technique is briefly described in the subsections that follow.

C.6.1 Manual Data Management Techniques

Manual data management techniques are those techniques which are accomplished by human skill, often aided by drafting, photographic, and photogrammetric equipment, but not by a computer. In general, these techniques are still used to carry out most tasks of spatial data handling.

Discussed below are selected manual land use and demographic data management approaches that might be employed by 208 agencies. Included are discussions related to the transfer and storage of data, as well as data manipulation and extraction.

Data transfer is defined as the way in which data in map, graphic, tabular, or report format from a variety of sources are grouped into one comprehensive data base. This process of moving data from various documents to form another data base can be done before the data are stored or at any time thereafter.

The transfer of descriptive data is generally a straightforward task of copying alphanumeric information by various methods such as photocopying, or hand-copying, and the summation of data into graphic or tabular formats. Reproduction facilities should be located in the immediate vicinity of the data center. A copier is a valuable asset for furnishing quick copies to users and can be leased for about $3,000 to $6,000 per year. Since the cost of constructing, equipping, and maintaining a photographic laboratory is generally prohibitive for a 208 agency in terms of anticipated benefits, arrangements should be made with another governmental agency or a commercial firm to provide any photographic services that may be required. The manual transfer of image data (photographs and maps), on the other hand, is a complex operation, particularly when the accuracy and the relationships between the elements must be retained. The transfer of image data may involve two types of data: planimetric or non-planimetric. Planimetric image data are positionally accurate and have a uniform linear scale. Topographic maps and orthophotographs are examples of planimetric image data. Conversely, non-planimetric data, such as aerial photographs, have inherent distortions that affect accuracies of measurement.

For almost all 208 land use planning efforts, it will be sufficient and cost effective for 208 agencies to work with documents in the non-planimetric form rather than incur the expense of producing a planimetric map or photograph.

The transfer of non-planimetric data can simply be completed by using visual

guidance aids (such as overlay grids at varying scales) or calculated reference points to transfer the necessary information to a new record base. If great care is exercised, a high degree of accuracy can be achieved. Light tables are useful for transferring transparent or translucent images. A simple and inexpensive light table can be constructed by placing a light bulb in a metal desk drawer and using a heavy frosted plate-glass or opalescent glass as the table surface. Reflecting projectors (overhead projector) are also useful for projecting the image of an illuminated photograph or other source material through a lens and one or more mirrors onto a map overlay or other manuscript. More expensive and accurate photogrammetric instruments that are not frequently found within a planning agency, but are often used by engineering and mapping agencies to transfer planimetric image data, include copy cameras, rectifiers, stereoscopes, and stereoscopic plotters and orthophotoscopes.[8]

The selection and arrangement of facilities for storage of maps, aerial photographs, reports and other land use and demographic planning data are important to assure ease of access and to provide adequate protection from dust, sunlight, dampness and careless handling. Maps are conveniently stored in map files. A typical steel map file case consisting of two five-drawer units with inside drawer dimensions of 50 x 38 x 2 inches costs approximately $650. Aerial photographs are commonly stored in vertical file cabinets but stiff cardboard dividers should be placed between flight lines for each of access and to prevent the photographs from curling. If cut from rolls, aerial photographic transparencies should be placed in plastic protectors to prevent damage from scratching and fingerprints.[8]

Data should be indexed using appropriate library card catalog procedures. Almost all standard map series such as USGS 1:24,000 (7 1/2 minute) maps, and county highway maps have graphic indexes available for map indexing purposes. Also, photo indexes of aerial photographs, which are made by creating a mosaic from exposures of specified areas and adding flight data, geographical references and other information, are very useful for locating specific aerial photographs.

No data base is very useful unless pertinent information can be extracted, manipulated, and used efficiently. Manual data manipulation operations are performed on data to make them more suitable for further processing, e.g. to improve their comparability, or to facilitate their retrievability. Data extraction involves the process of selecting and retrieving data from storage for subsequent analysis.

Manual data manipulation is often required to correct inaccuracies in the data and to overcome compatability constraints arising from the use of the data for analysis. Generally, some summarising or generalisation of the data does not substantially lessen the amount and value of the data, but care must be exercised to avoid the loss of any information. Depending on the type of data manipulation, time required for manipulation, volume of data, and possible use of the data, this operation can take place either when the data are prepared for storage or when they are retrieved from storage for use.

Specific manual data manipulations that may be required include:

1. Synthesis of data from various data sources into graphic or tabular formats
2. Map or photo scale changes and/or adjustments
3. Reclassification of descriptive data, e.g., changing feet to meters
4. Aggregation of data onto another aerial base, e.g., census tracts or transportation corridors to drainage basins
5. Generalization of data records based on similar descriptor codes to the same descriptor coding scheme (for example, deciduous forest and conifer forests into forest land) and
6. Coding of image data by using various grid patterns

Such data manipulations normally are labor-intensive, but labor requirements can be reduced by the use of calculators, grid overlays, and drafting equipment. A pantograph, which is a simple drafting device that mechanically links a drawing device to a cursor with which the original image is traced, is commonly used to copy and change map scales. More expensive optical transfer equipment not normally found in planning agencies, such as zoom transfer scopes, also can be used to superimpose photographs onto maps or

transfer map data onto another map.

In data extraction processes, the selection of specific data inputs is based on the requirements of the particular analysis to be made and on the knowledge of the contents of the data center from previous experience or data files. The time, effort, and costs involved in all types of search and identification operations are substantially influenced by how the data elements are organized and indexed. This is why the development of a well-organized data management system is so important in 208 planning efforts, whether that system be manually operated or computer-aided as discussed in the next subsection.

C.6.2 Computer-Assisted Data Management Techniques

More sophisticated than the manual data management techniques just discussed, computer-assisted techniques also may be utilized for land use data transfer, storage, and manipulation by 208 agencies. If the data base to be utilized is very large and/or very complex, or if computer models are to be used for subsequent analyses, the 208 staff should consider the use of computer-assisted data management.

Clearly, access to computer facilities is a prerequisite for the use of such techniques. Since many designated 208 agencies do not have an in-house computer capability, it may be necessary to arrange for computer access from other public agencies or from private consulting firms if computer-assisted data management techniques are selected. Rental fees and use rate expenses (excluding staff charges) for computer services for a 208 agency would likely range from $5,000 to $7,500 per year. It should be noted that an agency-wide data base that includes data relevant to other planning programs, e.g. transportation planning, may be the best approach if an investment is to be made in a computer-assisted data management system. This would also facilitate accounting for these other kinds of planning programs in the 208 planning process. It would also provide a solid data base that could be easily updated and quickly accessed as the agency moves into the continuing planning process after the initial 2 year 208 planning effort.

It is important to recognize that, as with manual data management, special care must be taken to avoid errors in the data placed into the computer-assisted data management system. Any attempt to use other than error-free data files can have disastrous effects on subsequent analyses, since the computer can only deal with conditions that have been explicitly defined, whether correctly or incorrectly.

It is also important for the JOB practitioner to recognize that a total data management system can be conceived of as a logical set of techniques, some performed manually and others with the use of the computer, with the objective being to optimize the performance of the total system. Thus a combination of manual and computer-assisted techniques may provide the designated JOB agency with the optimal approach to data management.

C.6.3 Selecting a Data Management Approach

While it is not possible to deal with the variety of agency-specific data management needs in a manual of this type, this subsection provides some general guidance on selecting an approach to data management, whether that approach uses manual, computer-assisted, or some combination of the two types of techniques.

The assessment of the differences between manual and computer-assisted approaches to data management involves the following considerations:

1. Data complexity
2. Operational flexibility
3. Costs
4. Time requirements
5. Personnel requirements.

The paragraphs that follow briefly discuss each of these considerations.

The complexity of the data base is important to evaluate before the selection of a data management approach is made. If the data base is not very complex, and if the data are already or can be aggregated easily by hand, then manual

data management techniques are most appropriate. However, as the complexity of the data base and the volume of the data at hand increase, computer aided techniques generally are more desirable than manual techniques.

With respect to operational flexibility, there are advantages and disadvantages to both manual and computer-assisted techniques. Manual approaches are very flexible as long as there is enough time available to do the data manipulation. On the other hand, computer-assisted approaches generally are more rigidly structured, but in general can be programmed to provide data management flexibility much quicker than manual techniques.

Clearly, cost considerations are extremely important in the selection of an appropriate data management system. It is impossible to provide a meaningful range of costs for manual data management systems here because of the wide range of data management needs in individual 208 agencies. As mentioned previously, rental fees and use rate expenses (excluding staff charges) for computer services range from $5,000 to $7,500 annually. For 208 agencies with in-house computer capability, the economics of computer-assisted data management will be more favorable. In-house expertise and/or consultant services should be utilized to provide the specific cost figures for manual or computer-aided data management systems tailored specifically to the agency's needs.

In terms of time requirements, the 2 year time frame of the 208 program may significantly affect the desirability of going to a computer-assisted data management system. If in-house computer facilities do not exist, it may take too much time to organize the data base, develop or acquire the computer capability, and get the data into the system. If the in-house capability is already present, or can be quickly acquired, computer-assisted techniques become more desirable, especially since they commonly expedite the subsequent data analysis effort. It should also be noted that manual techniques might be used for the initial 3 year planning period while plans are formulated for the use of computer-aided systems in the continuing planning process. In this instance, the manually managed data base should be prepared in a manner that will expedite conversion to a computerized data

base at some subsequent date.

Finally, the personnel requirements for manual and computer-assisted approaches are somewhat different. Manual techniques may utilize existing agency staff to a large extent while computer-aided approaches require computer science expertise, e.g. computer programmers, and data management specialists. Even if consultants are utilized, it is recommended that some in-house expertise in computer science be acquired to effectively direct and coordinate the work of the consultants.

Each of the above considerations should be included in the assessment of alternative approaches to data management. How they are used, and the relative importance of these considerations in the decision-making process must be left to the individual 208 agencies.

C.7 Inventory of Land Use and Demographic Data Analysis Techniques

The discussion in this section of the Appendix covers a wide range of land use and demographic data analysis techniques from the simple, traditional approaches to the more complex, sophisticated approaches. The emphasis is on the practical application of such techniques in the context of 208 planning. Each technique will be discussed in terms of the following elements:

1. A brief description of the approach, and the kinds of input data required
2. A description of the output of the technique, and how the output might be used with other tools/techniques, such as water quality models, to formulate and evaluate water quality management alternatives
3. An outline of potentially significant constraints on the use of each technique, along with suggestions on how to avoid potential problem areas
4. A summary of the strengths and weaknesses of the approach relative to the 208 program
5. An estimate of relative costs for each technique.

C.7.1 Relatively Simple, Low-Cost Techniques

This subsection will discuss techniques for demographic and land use analyses at the relatively simple end of the spectrum of potential techniques. These techniques make maximum use of the existing secondary data bases likely to be available to the 208 planner. In terms of cost, they are the least expensive techniques to implement, although they are not as analytically sophisticated as some of the other approaches.

Demographic and economic projections are very important to subsequent land use analyses. The next few paragraphs outline a simple technique for performing the demographic projections for the 208 program which involves the use of data available from the U.S. Bureau of Census, and the Social and Economic Statistics Administration, both in the U.S. Department of Commerce. Data from both these sources, namely census and OBERS data respectively, are possibly already utilized within each designated 208 planning agency for other planning programs. Data collected from the above two sources (see Section C.5) might be utilized by the 208 agency as a baseline from which historical population growth rates can be extrapolated by 5 year increments for the 20 year planning period. The output would be population projections by SMSA, County, and/or township for the 208 region. These data would then serve as inputs to subsequent land use calculations. Using this sort of desk top extrapolation technique assumes that the historical growth rates will hold over the next 20 years. Modifications of the growth rates can be made to generate alternative scenarios for the future.

The use of OBERS Series E population data is also a very attractive, relatively simple option for the 208 agency to use for its demographic projections. Of particular interest to 208 agencies is Volume III, where the data are aggregated by water resources regions and subareas. The units of aggregation in this Volume include twenty major regions defined by hydrologic boundaries that are further divided into tributary and main stem reaches entitled water resources subregions. The subregions cut across county lines

to coincide with drainage patterns. However, the water resources subareas are actually county-defined approximations of the actual hydrologic units they represent. In some instances, the 208 agency's planning area may closely approximate the water resource subarea boundaries, in which case the population projections can be utilized directly for the increments given. In other cases, one of the other levels of data aggregation, e.g. by Bureau of Economic Analysis region, may be easier for the 208 agency staff to work with. This determination must be made by comparing the study area boundary with the various data aggregation boundaries, and picking the most appropriate one. Whatever the case, the population data are available by county from 1929 and are projected to 2020. Using these data, the 208 planner need not extrapolate as mentioned previously with the census data since the projections are given in appropriate 5 year intervals. Thus, the OBERS projections are of direct utility to subsequent land use projections. The technique is simple to complete and is likely even less expensive than having the staff extrapolate from census data. One note of caution is in order, however. The assumptions made to arrive at the OBERS projections are explicitly stated in Volume I. (See Section C.5). If these assumptions represent significant violations of the prevailing conditions in the subject 208 region, then extrapolations using different assumptions would be more appropriate.

It should also be noted that many states have their own programs that generate population and economic projections. Likewise, many universities engage in similar projection activities. It is conceivable that projections formulated from such sources would be more appropriate for some 208 programs. For example, if there is one or more 201 planning efforts ongoing in a given 208 region and the 201 program is using state projections, the 208 program should consider the need for consistency in the use of the same state projections.

The simplest approach to the land use element of 208 is to make maximum use of existing land use maps, as well as any maps of projected land use configurations in the study area. Using these maps (if available), the major drainage areas in the 208 region should be superimposed upon the existing and projected land use configurations. Once this is complete, a planimeter

can be used to calculate the square mileage and/or acreage of the various land use types in each drainage area. This information will be useful in making water quality projections when associated with precipitation data and estimated runoff characteristics. These land use/drainage area maps can also be used to display the location of major point and nonpoint sources in the 208 region.

Where it becomes necessary to estimate the future land use configuration of a region, (for example the existing land use projections may be for the year 2000 without any indication of what the 1980 and 1990 configurations might be), the population projections can be used along with existing zoning maps, which commonly indicate residential densities, to estimate the extent of urban fringe development that would occur over a given time frame, e.g. over 5 year intervals. The allocation of anticipated population increases using graphic overlays of present zoning restrictions will provide the 208 planner with a picture of how the existing land use pattern might be expected to change incrementally over the 20 year study period. This information can again be utilized as an input to the water quality analyses by using a planimeter to derive acreage figures for each type of land use. It is anticipated that the greatest change over time will take place on the urban fringe. Thus, land uses within some drainage areas may be expected to change very little over the 20 year planning period.

The above techniques for estimating future land use patterns are relatively simple and inexpensive because they depend upon existing data and table-top analyses. They also do not have the sophistication and the analytical flexibility that is characteristic of some of the more complex techniques. The specific costs of the techniques are dependent upon what kinds of existing and projected land use maps are available at the local level, and for what future time periods. In most cases, the land use categories used for these maps will be compatible with the subsequent use of the information in the 208 planning process. This should be checked, however, and appropriate modifications in land use categories made if they are not useful for subsequent analyses.

C.7.2 Intermediately-Complex, Moderate-Cost Techniques

These techniques still involve only manually executed analyses, but include a more careful look at alternative futures in terms of land use/water quality relationships than the simple techniques described previously. Some primary data collection, e.g. aerial photography, will likely be necessary to perform these analyses instead of complete reliance on existing secondary data sources.

The demographic analyses in this category will still utilize, as a baseline, the census and/or OBERS data discussed previously. The principal difference between this approach and the simpler approaches is that a simple extrapolation of past growth rates is only one possibility evaluated. The 208 planner using the intermediately complex approach postulates alternative futures based upon other sets of conceivable assumptions. Thus a range of future growth scenarios is calculated based upon explicit assumptions made using the census or OBERS data as a baseline. A range of population growth scenarios is valuable to consider in the formulation of areawide plans that are sensitive to different alternative futures for the study area.

Again, this technique involves manual calculations using reasonable assumptions upon which to base population projections that differ from those assumptions found in the sources mentioned previously. This approach also allows for the incorporation of region-specific factors that may significantly inhibit or facilitate population growth, e.g., rapidly declining in-migration, that may not be accounted for in other projections.

The land use analysis techniques classified as intermediately complex attempt to incorporate more land use-related variables into the analysis, e.g., land use suitability based upon the physical features of the land surface. The most common example of a technique of intermediate complexity is the overlay approach conceptualized by Ian McHarg in his book Design with Nature.[12] A version of this approach the Land Use Decision-Making System (LUDMS), is described in an EPA publication entitled, "A Land Use Decision Methodology for Environmental Control."[13]

[illegible] utilizes a technique that focuses on the development of environmental analysis component maps. This approach consists of the formulation of a base map of appropriate regional scale and series of clear plastic overlays, each mapping a land use parameter relevant to the land use/water quality relationship. The base map should be relatively uncluttered, but should include major natural and man-made features, e.g. streams, lakes, significant political boundaries etc. The overlays should map the occurrence of key parameters of interest such as:

1. Aquifer recharge areas (based on regional geology)
2. Major point and nonpoint dischargers (from NPDES permits and other available water quality information)
3. Areas unsuitable for septic tank systems (based on soils data, regional geology, and water quality data inputs)
4. Areas with steep slopes (from USGS topographic maps)
5. Critical fish and wildlife habitat (from numerous potential sources, e.g. State Departments of Natural Resources etc.)
6. Existing water and sewer service areas, and projected service areas (from local public utility departments etc.).

These overlay maps can be utilized to illustrate development constraints related to water quantity and quality considerations. These constraints could, in turn, be used as a basis for modifying future land use projections in alternative ways that would be more sensitive to water resource management concerns.

In addition, the overlay technique can be used to identify and evaluate regions where development opportunities exist which will minimize adverse impacts on regional water resources, and the environment in general.

The map overlay from the above analysis can be utilized in conjunction with demographic projections and existing zoning maps to derive alternative future land use configurations for the study area. The procedures for this part of the analysis are similar to those previously described in the section on relatively simple techniques. The final output of the analysis will be one

or more land use configurations that represent alternative future scenarios for the region. These future configurations should be more sensitive to water resource management concerns because this technique provides for a more explicit and intensive consideration of water quantity/quality concerns than the traditional land use planning process, upon which the more simplified techniques are more dependent.

The alternative configurations that evolve out of the analysis can then be tabulated in percentages of each land use type present in each drainage area in the planning region. A planimeter can be used to estimate the acreage of each land use type in each drainage area. These figures can then serve as an input to the water quality evaluations. These quantitative values can also be better tempered with qualitative judgement using this moderately complex approach, because of the more focused consideration of water resource-related parameters.

The overlay approach is likely to be more expensive than the simple approach described in the previous subsection due to the additional staff time involved in working with additional variables. The 208 planner needs to decide whether the additional information provided by the overlay approach is worth the additional expenditure. This decision will depend, in part, upon the confidence the planner has in existing land use projections, and in their sensitivity to water quality considerations.

C.7.3 Relatively Sophisticated, High-Cost Techniques

The final category of demographic and land use analysis techniques involves the relatively sophisticated computer
that follow discuss several such approaches, some of which are being employed in ongoing 208 programs.

One example of a computerized demographic projection model is the Demographic and Economic Modeling System (DEMOS) developed by Battelle's Columbus Laboratories. DEMOS is useful for the following applications relevant to 208 planning:

1. Projecting population characteristics by single year, five year or other appropriate intervals, and by political subdivision
2. Analysing spatial patterns of population distribution
3. Analysing migration propensities
4. Analysing demographic structure and labor force potential.

Items 1 and 2 above are particularly relevant to the land use element of the 208 planning process.

DEMOS utilizes many facets of previously developed projection tools such as the cohort survival technique, but combines these concepts with region-specific factors that influence population and employment growth. For example, the model concentrates upon relationships between migration and unemployment, birth rates and unemployment, labor force participation rates and the ratio of employment to population, and labor availability and the demand for labor. Through these relationships, economic and demographic conditions in a given region can be interrelated via demographic, economic, and feedback submodels to provide the practitioner with realistic projections that can be modified to reflect varying assumptions. The model's basic outputs are population by age, employment by industry, and labor force by age, although numerous other variables may also be explored in the model.

It should be noted that one of the attractive aspects of DEMOS and some other similar models such as PEMOS, a model used by the Southeast Michigan Council of Governments (Detroit) in their 208 program, is that it is available in a computer-interactive form. This is to say that the planner can sit at a computer terminal, and with very little previous experience, perform regional projections with varying assumptions. The computer program actually leads the user via a series of questions through the projection process, affording him or her the opportunity to explore the model's assumptions, and the mathematical equations upon which the model is based.

The computerized approach to demographic projections has advantages and disadvantages that should be considered by the 208 planner before an approach

is selected. The primary advantages are the flexibility the models afford the user in exploring alternative futures quickly and relatively inexpensively after the "front-end" investment is made, and the increased sophistication and regional sensitivity provided by such an approach. The major disadvantages are that the acquisition of the computer access, the support facilities, and the model are relatively expensive relative to reliance on census or ORERS data. Projections for a 5 county 208 area down to the township level cost in the range of $23,000-27,000 including staff time. This disadvantage might be overcome somewhat by working out a cost-sharing arrangement with other programs and/or agencies, since most planning efforts rely upon good demographic projections. The use of such models also requires staff expertise that may not be present in some 208 programs.

An exhaustive discussion of other demographic projection techniques, including computer models, is found in Demographic Information for Cities: A Manual for Estimating and Projecting Local Population Characteristics written by Peter A. Morrison (see Annotated Bibliography section of Appendix I).

The Toledo, Ohio, 208 program has employed a computer-based information system called the Land Resources Information System (LRIS).[14] LRIS serves as a good example of a relatively sophisticated land use data management and analysis technique. It is designated to measure the co-occurrence of land resource features in a manner that facilitates the measurement of an area's potential for nonpoint source pollution.[14] The technique involves a multivariate analysis on a watershed basis of the impact on water quality of land cover, soils characteristics, and slope variables. The data inputs to LRIS include land cover data derived from an analysis of recent color infrared aerial photography; soils information from available soil surveys; elevation data to the nearest 5 feet derived from USGS 7-1/2 minute quadrangle maps; and location information identifying points by minor watershed, political subdivision, and in metropolitan Toledo, by traffic zone. Special care was taken in the formulation of LRIS to insure the aggregability of data into larger units.

The data are organized according to a 4 hectare rectangular grid system that

covers the entire 2006 square mile study area. An unaligned random sampling technique is used to place a single point within each grid cell at which the data for the different variables is recorded to represent the entire cell. The only exception is with the land cover variable for which two decisions are made for each cell, namely the dominant land cover in the entire cell, and the exact cover at the randomly placed point.

By using the data system described above, the Toledo Metropolitan Area Council of Governments is able to identify the co-occurrence of land resource characteristics, e.g. little vegetative cover, and steep slope, that significantly affects regional water quality. To date LRIS has been utilised as a tool for analysing nonpoint source pollution, as well as for generalised land use planning.

The advantages of such a technique are significant. First of all, the data base is up-to-date for the analyses. The data are well-organised, highly accessible, easy to store, and the computer program facilitates the analytical work. The same system is also very relevant to other ongoing planning programs, e.g., transportation, coastal zone management, and solid waste programs.

The front-end costs of developing such a system are substantial compared to the less sophisticated techniques discussed previously. This kind of approach also requires some in-house staff capabilities in computer science, and data management.

Another land use model of potential interest to 208 planners, is a model developed by A.B. Corbeau and C.F. Meger to evaluate future land uses in the St. Louis SMSA.[15] The model is designed to allocate anticipated population and employment in 10 year increments to parcels of land categorized into four categories:

1. Industrial
2. Residential
3. Commercial, and

4. Public.

Desirability criteria relative to each land use type drive the land allocation process in the model. The data inputs for the model include economic data such as the number of people engaged in a particular land use-related activity; regional population projections; and parameter override factors that permit specific anticipated land use changes as well as controls on population density. The output of this model includes summary reports on the land allocation process by land use type, along with what are called diagnostic reports containing det[illegible] information on each land unit being modelled. This kind of information would be useful in the 208 planning process for anticipating conversion of one land use type into another. This information can then be translated into anticipated water quality impacts using tools discussed elsewhere in this Manual.

The general advantages and disadvantages of the St. Louis model are much the same as those discussed previously relative to the Toledo approach. More specifically, this particular model is quite flexible, and could be applied to most 208 regions. A weakness of the model, however, is that the ranking of the desirability of certain land development is subjective.[15]

One final model of possible applicability to 208 planning is the Dynamic Land Use Allocation Model III (DYLAM III) developed by David Seader and Peter Masseri.[16] This model has been utilized in a water supply study, in a flood plain and stormwater management study, and for numerous long range land use planning efforts.

In essence, DYLAM III simulates land use location decisions allowing for the projection and analysis of probable development.[16] The model also has the capability to simulate the impact of proposed facilities and alternative policies on land use patterns.

In terms of input data requirements, DYLAM III is quite flexible in that it can accomodate any information that can be mapped in a grid cell data format. For example, one study that used the model involved, in part, the following

mapped data elements:[16]

1. Moderately sloping land
2. Steeply sloping land
3. Flood plains
4. Swelling soils
5. Water and sanitation districts
6. Industrial parks
7. Lakes and streams.

The model can accommodate up to 60 such elements, and the elements can be tailored specifically to the problem at hand, e.g., characterizing the land use/water quality relationship.

The basic work of the model is to geographically distribute anticipated increments of development. It should be noted, however, that the total estimated acreage of new development must be an input to the model. The model's work involves five basic tasks described briefly as follows:

1. Search for sites, defined as grid cells
2. Determine a grid cell's suitability for development based on input locational requirements
3. Compute a numerical attractiveness of suitability score
4. Rank all developable grid cells from the most to least attractive based upon the numerical scores
5. Allocate the amount of new development specified to the most suitable grid cells.

The conceptual framework of DYLAM III lends itself to a potential 208 application in which the locational requirements for development include relevant water quality and quantity considerations.

The output of the model includes both tabular and mapped information. The maps include present and projected land use configurations at the end of each time period used. The maps highlight where new development occurred. The tabular information indicates the projected order for site development.

The model also has the capability to produce maps illustrating one or more data base elements superimposed on one another. The composite maps produced in this manner can be very useful in highlighting potential water quality problems associated with projected development as discussed in the previous subsection.

The model has the same advantages and disadvantages that the other computer models discussed have had, along with some DYLAM III specific advantages. The model is very flexible in terms of being applicable to a broad range of potential land use-related concerns, including those of the 208 program. The mapping capability is very useful in most applications, including those for 208. The model can also be easily fitted to a broad range of geographic areas, from a single municipality to a large multi-county region.

There are a couple of potentially significant disadvantages of DYLAM III also. Land use development can only be simulated by rectangular grid cells in the model. In addition, only one land use can be assigned to each grid cell at a time, and all the data utilized in the model are nominal data. That is, either the data element is present or absent in a given grid cell. Various degrees of presence cannot be accommodated.

Additional material on potentially relevant land use planning models may be found in the following two documents (See Annotated Bibliography):

1. "Review of Operational Urban Transportation Planning Models", U. S. Department of Transportation
2. "Models and Methods Applicable to Corps of Engineers Urban Studies", U. S. Army Engineer Waterways Experiment System

C.8 Appendix Summary

This Appendix has attempted to provide the practicing 208 planner with some assistance in developing the land use element of the areawide water quality management program. The focus has been on the following topics:

1. identification of land use data needs
2. identification of existing data sources and characteristics

3. Matching of data needs with available data sources
4. Collection of land use data
5. Identification of demographic and land use data management techniques
6. Inventory of demographic and land use data analysis techniques.

In each case, the discussion has been structured to provide the practitioner with a range of potential approaches to land use data collection, management, and analysis, from simple to complex. As mentioned at the outset, this Appendix is not designed to be prescriptive in any way, but rather is meant to provide a "shopping list" description of potential approaches along with supporting documentation. The references that follow and the Annotated Bibliography in Appendix F provide the reader with sources of additional information on topics discussed herein that may be of further interest.

C.9 References

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3. University of Wisconsin-Madison, Institute for Environmental Studies, "Data Needs and Data Gathering for Areas of Critical Environmental Concern: Part I - Summary Report," University of Wisconsin-Madison, Madison, Wisconsin 53706, September 1975, pg. 120.
4. Anderson, J. R., Hardy, E., and Roach, J. T., 1972, "A Land Use Classification System for Use with Remote Sensor Data," *Geological Survey, Circular 671*, Washington, D. C.
5. *Federal Register*, December 12, 1974 (39:240) Title 24, part 600.
6. Mansel, Paul W., Leivo, Carl E., and Lewellen, Michael T., "Regional Land Use Classification Derived from Computer-Processed Satellite Data," *Journal of the American Institute of Planners*, April 1976, pgs. 153-164.
7. Examples of in-depth discussion of population projection methods can be found in:
   Atchley, Robert C., "Population Projections and Estimates for Local Area," *Scripps Foundation for Research in Population Problems*, Miami University, Oxford, Ohio, 1970. or:
   Morrison, Peter, "Demographic Information for Cities: Manual for Estimating and Projecting Local Population Characteristics," *Rand Corporation*, June 1971.
8. U. S. Department of Interior, "Information/Data Handling: A Guidebook for Development of State Programs," (unpublished draft report) July 1975, pgs 110-116.
9. For further discussion on this mapping technique see:
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10. Chapin, F. Stuart, Jr., "Urban Land Use Planning," *University of Illinois Press*, Urbana, Illinois, 1965, pgs. 277-291.

11. Such a land use study from LANDSAT data undertaken by the Ohio-Kentucky-Indiana Regional Council of Governments (OKI) in their 208 program. For more information contact:

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OKI
426 East 4th Street
Cincinnati, Ohio 45202
(513) 621-7060

12. McHarg, Ian, "Design with Nature," *Doubleday and Company, Inc.*, Garden City, New York, 1971.

13. U. S. Environmental Protection Agency, Office of Research and Development, "A Land Use Decision Methodology for Environmental Control," Washington, D. C., March 1975, pg. 47.

14. Toledo Metropolitan Area Council of Governments, "Development and Utilization of Regional Land Use Planning Data Base Using Modern Computer Technology," unpublished concept paper, April 1976.

15. Corbeau, A. B., and Merger, C. F., "A Land Use Model for the St. Louis SMSA," University of St. Louis, St. Louis, Missouri, Draft Report, November 1973.

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USGPO: 1976 - 757-056/5404 Region 5-11

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

* * * * * * E R R A T A * * * * * *

The Program chart entitled: EPA Programs in Support of State, Regional, and local Environmental Planning (September, 1976) has juxtaposed the Drinking Water Program labels in the wrong order. The correct sequence should be:

1. Public Water Supply Systems
2. Underground Injection Control
3. Sole Source Aquifer Program

SELECTED FEDERAL PRO

		Responsible Office	Legislative Mandate	Program Objectives	Federal Register	Guidelines	Significant Dates	Designation	Implementing Level of Govt
HUD	COMPREHENSIVE PLANNING ASSISTANCE 701								
HUD	FLOOD PLAIN MANAGEMENT								
DOT	FEDERAL-AID HIGHWAY PROGRAM								
DOT	URBAN MASS TRANSPORTATION TECH STUDIES								
DoD	URBAN STUDIES PROGRAM								
COMMERCE	COASTAL ZONE MANAGEMENT								
COMMERCE	STATE & LOCAL ECONOMIC DEVELOPMENT PLANNING GRANTS								
WRC	COMP WATER & RELATED LAND RESOURCES PLANNING								
	LAND & WATER								

B

FEDERAL PROGRAMS RELATED TO REGIONAL PLANNIN

Significant Dates	Designation	Implementing Level of Gov't	Planning Area	Required Coordination			Time Horizon	Output	Sanctions for Non-Compliance	Citi Par Fea
				Within Agency	Other Fed Agencies	Non-Fed Agencies				

ATED TO REGIONAL PLANNING*

Coordination		Time Horizon	Output	Sanctions for Non-Compliance	Citizen Participation Requirements	Funding Availability	Other Programs
...er Fed ...encies	Non-Fed Agencies						

	MANAGEMENT		[illegible]	[illegible]			[illegible]	
DOT	FEDERAL-AID HIGHWAY PROGRAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DOT	URBAN MASS TRANSPORTATION TECH STUDIES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
DoD	URBAN STUDIES PROGRAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COMMERCE	COASTAL ZONE MANAGEMENT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COMMERCE	STATE & LOCAL ECONOMIC DEVELOPMENT PLANNING GRANTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WRC	COMP. WATER & RELATED LAND RESOURCES PLANNING	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DOI	LAND & WATER CONSERVATION FUND	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
USDA	WATER & WASTE DISPOSAL DEVELOPMENT GRANTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
USDA	RESOURCE CONSERVATION AND DEVELOPMENT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STATE SOLID WASTE MANAGEMENT PLANNING	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TECHNICAL ASSISTANCE FOR SOLID WASTE MANAGEMENT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SOLID WASTE GUIDELINES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RADIATION PROGRAM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EXPERIMENTAL PESTICIDE USE PERMITS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STATE PESTICIDE REGISTRATION	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COOPERATIVE PESTICIDE ENFORCEMENT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CERTIFICATION OF PESTICIDE APPLICATORS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TECHNICAL ASSISTANCE FOR NOISE CONTROL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Standards	Deadlines	Functions of Facilities	Court Actions	Public Participation	Implementing Agency	Implementing Agency of Government	Planning Area	Time Horizon	Budget	Special Authorities	Other
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	Implementing Agency of Government	Planning Area	Time Horizon	Output	Required Resources	Funding Availability	Interagency Coordination	Interagency Agreements	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SOLID WASTE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	RADIA-TION
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	PESTICIDES
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
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EPA

STATE, REGIONAL

	Legislative Mandate	Responsible EPA Office	Program Regulations	Federal Register	Program Guidance	Pollution Sources and Mediation Criteria	Pollutants
STATE IMPLEMENTATION PLANS							
PREVENTION OF SIGNIFICANT DETERIORATION							
AIR QUALITY MAINTENANCE							
TRANSPORTATION CONTROL PLANS							
NEW SOURCE REVIEW							
STATE & AREAWIDE WATER QUALITY MANAGEMENT PLANNING							
WASTE TREATMENT FACILITIES PLANNING							
NATIONAL							

EPA PROGRAMS IN SUPPORT OF

ONAL, AND LOCAL ENVIRONMENTAL PLANNI

	Pollutants	Standards	Deadlines	Sanctions or Penalties	Court Actions	Public Participation	Designating Authority	Implementing Units of Government	Planning Area	Time Horizon	Output	Required Assistance

PPORT OF

RONMENTAL PLANNING

Authority	Implementing Order of Government	Planning Area	Time Horizon	Output	Required Resources	Funding Availability	Interagency Coordination	Interagency Agreements	
									AIR QUALITY
									WATER Q

DETERIORATION							
AIR QUALITY MAINTENANCE							
TRANSPORTATION CONTROL PLANS							
NEW SOURCE REVIEW							
STATE & AREAWIDE WATER QUALITY MANAGEMENT PLANNING							
WASTE TREATMENT FACILITIES PLANNING							
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM							
CLEAN LAKES							
UNDERGROUND INJECTION CONTROL							
SOLE SOURCE AQUIFER PROGRAM							
PUBLIC WATER SUPPLY SYSTEMS							

									AIR QUALITY
									WATER QUALITY
									DRINKING WATER